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ANNALS
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THE STATUS OF THE FAMILY ARCHAEIDAE AND THE GENUS LANDANA

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The family Archaeidae was established by C. L. Koch and G. C. Berendt in their work published posthumously in 1854. No definition of the family was given, but the characters of the genus *Archaea* were given even in greater detail than was customary at the time. Three fossil species from Baltic amber were included in the genus, described and figured. These are *A. paradoxa*, *A. conica* and *A. laevigata*. A. Menge who edited the work of Koch and Berendt, added, in a footnote on page 22, to the above three species three other species, *A. sphinx*, *A. incomta* and *A. hyperoptica*, also from the Baltic amber. In 1881 O. P. Cambridge described the first recent species of Archaea from Madagascar under the name of *Eriauchenus workmanni*. In 1883 Simon established the genus *Landana* for a new species *L. petiti* from the Congo, which he placed in the family Archaeidae. In the same year he described a fossil spider from the Baltic amber under the name *Archaea pugneti* and a recent spider from Cape Horn which he referred to a new genus *Mecysmaucheniu*s. Simon placed this genus with its type species *M. segmentatus* in the family Archaeidae. In 1893 he described a new species of Landana from Venezuela, *L. cygnea*, still placing it in the family Archaeidae. Only in 1895 did Simon remove the genus Landana from the family Archaediae into the group Meteae, subfamily Tetragnathinae of the family Argiopidae as delimited by him in his Histoire Naturelle des Araignées. His decision was based on the marked difference in the shape of the cephalothorax and chelicerae in the two sexes of Landana and on the fact that the web of the female *L. cygnea* is similar to

that of Meta, i. e., has the structure of a geometric orb-web. In 1904 Simon described another species of Landana, *L. edwardsi*, from Chile, referring it naturally to his subfamily Tetragnathinae. In the same paper he mentions a *Landana wilsoni* Simon which "represents the genus in the extreme South of America, is much larger and resembles in size and somewhat in coloration our Meta merianae Scopoli" (p. 95, my translation, A. P.). I am unable to find the description of this species, nor is it mentioned by Dalmas. In 1907 Tullgren described *Mecysmauchenius nordenskjöldi* from Patagonia. In 1917 Dalmas described *Landana lautiuscula* from New Zealand. In 1919 Hewitt described *Archaea godfreyi* from South Africa and in 1929 Butler described *Archaea hickmani* from Australia. Thus up to the present we know seven fossil and three recent species of Archaea and two species of Mecysmauchenius comprising the family Archaeidae, and four species of the genus Landana.

NEW EVIDENCE ON THE ARCHAEIDAE

In August, 1938, I have captured two mature males of a new species of Landana, *L. spinosa* on the Barro Colorado Island in the Gatun Lake, C. Z. A detailed description of this species is given below. The study of its external and internal anatomy led me to a reinvestigation of the structural characters and internal anatomy of *Archaea workmanni* of which I had two immature females in the penultimate instar and a mature male, all from Madagascar. As a result the status of the family Archaeidae had to be reconsidered in the light of the new evidence and the genus Landana once more reassigned to the family under which it was originally placed by Simon. At the same time a new definition of the family Archaeidae had to be given and this had to be done not for the mere purpose of so widening it as to make the inclusion of the genus Landana in the family Archaeidae possible, but because several of the characters of the genus Landana make its separation from the typical representatives of the family Archaeidae impossible.

THE VIEWS OF KOCH AND BERENDT

As already mentioned, Koch and Berendt did not give a definition of the family Archaeidae. In the introductory remarks on page 1 they make the following statement concerning *Archaea paradoxa*: "Nicht ein Merkmal nähert sich auch nur im Entferntesten den Characteren der Familien der jetzigen Spinnen. Sie steht daher ganz allein im Systeme." The authors give no explanation of their categorical statement. Only two of the characters given in their definition of the genus may be pointed out in support of their view, namely the shape of the head and the length of the chelicerae, the other characters presenting no peculiarities whatsoever. Of the insertion of the palp on the maxilla, a char-

acter stressed in the later years by other arachnologists, they state that it is on the side of the maxilla—"auf den Kinnladen zur Seite eingelenkt." This statement is borne out by the figure of *Arachaea paradoxa* on plate II and by a further statement on page 20, "Die weiblichen Taster haben nicht ganz die Länge der Fresszangen, sind etwas schmächtig, sehr dünn, an den Seiten der Kinnladen etwas vor der Mitte der Länge auf einem Hügelchen eingelenkt." The palpi of *Archaea conica*, according to the authors, are not clearly visible, nor are they shown in their figure of the species. In the male *A. paradoxa* and in *A. laevigata* the insertion of the palp is figured as being on the dorsal surface of the maxilla, but no statement to that effect can be found in the text. Not having seen the specimen I am not in the position of forming a definite opinion in the case, but in the light of the evidence derived from a study of *Arachaea workmanni* I believe that the figures in question are incorrectly drawn. Considering the difficulties involved in the study of amber material and the imperfection of instruments available a hundred years ago an error of interpretation of this kind is very likely and quite excusable.

Menge who edited the work of Koch and Berendt and supplied it with comments based on his own very extensive knowledge of spiders did not agree with Koch's view that the Archaeidae are unique among spiders. On page 22 Menge writes: "Die von Koch mehrfach hervorgehobene starke Abweichung dieser Spinnengattung von noch lebenden kann ich nicht finden. Die Trennung des Kopftheils des Vorderleibes ist bei *Myrmica nigra* deutlicher bezeichnet als bei Archaea, und die langen Oberkiefer oder Fangklauen kommen bei Salticus, Tetragnatha und andern Gattungen vor. Die Stellung der Augen ist aus der Erhöhung des Mitteltheils des Kopfes hervorgegangen und finden sich by Micryphantes und Bolyphantes, von denen viele Arten einen erhöhten Kopftheil tragen, eben so bedeutende Abweichungen. Nach der ganzen Körperform und Haltung, so wie durch die ziemlich horizontal wie zur Lauer ausgebreiteten Füsse, scheint sie mir Tetragnatha und somit der Familie der Epeiriden am nächsten zu stehen."

THE VIEWS OF EUGENE SIMON

Simon in his Histoire Naturelle considered the family Archaeidae as one of the most specialized among spiders, "l'une des familles les plus spécialisées de l'ordre des Araignées." (p. 933). At that time however, only one living species of Archaea and one of Mecysmauchenius were known. Of the fossil species Simon knew only four, having overlooked the three species of Menge, mentioned above. Only immature specimens of Archaea were at his disposal. Of Mecysmauchenius he had mature specimens of both sexes. Thus his knowledge was of necessity limited. He was, however, already familiar with both sexes of Landana. It was, therefore, not some single, distinctive character, but the *combination of characters* that decided Simon to restrict the family to the two genera, Archaea and Mecysmauchenius. Had he been more fortunate in possessing greater material he may have reached other conclusions. The generic affiliation of *Archaea godfreyi* and *Archaea hickmani* as well as that of *Mecysmauchenius nordenskjöldi* is beyond question. Yet they

present certain modifications of characters found in *Archaea workmanni*. The generic affiliation of *Landana edwardsi* and *Landana lautiuscula* is much more uncertain. The male in both cases remains unknown, yet it happens to be the male which presents the distinctive characters of the genus Landana. In favor of *L. edwardsi* being a Landana are only two circumstances: the fact that Simon was familiar with the females of *L. petiti* and *L. cygnea* and had specimens for comparison, and the shape of the chelicerae, which is referred to in Simon's description as "chelae validae et longae, laeves." However, no figures are given of the species and the description itself singularly lacks reference to all important and distinctive characters and is therefore entirely inadequate to be of any use in discussing generic characters. For the present *L. edwardsi* must remain of questionable generic affiliation.

The case of *Landana lautiuscula* is still worse. It is true that Dalmas gave a careful description of the female and supplemented it by four figures. Unfortunately many of the characters given by Simon in his definition of the genus Landana do not agree with the description given by Dalmas. For example, Simon says about the posterior eyes, "medii a lateralibus quam inter se multo remotiores," while Dalmas writes: "les yeux médians sépares l'un de l'autre de leur diamêtre, et de leur rayon seulment des lateraux," that is just the reverse of the condition in Landana. Of the size of the anterior eyes Simon says "medii lateralibus saltem duplo majores" while Dalmas writes: "yeux subégaux, sauf les médians antérieurs un peu plus gros." The characters of the chelicerae are given by Simon as follows: "Chelae feminae sat longae et robustae, margine inferiore sulci dentibus quinque, quatuor inter se subcontiguis, 1^0 sat valido, reliquis minutissimis, dente ultimo ab alteris remoto. "Dalmas states that in *L. lautiuscula* the inferior margin has only two teeth which are weaker than those of the superior margin. In the absence of a male it is impossible to say that these are merely specific differences and that Simon's definition of the genus Landana should be so modified as to include the species *L. lautiuscula*. But if we retain Simon's definition of Landana, then *L. lautiuscula* must be removed to some other genus. Not having seen the specimen I am not prepared to suggest the genus to which it should be assigned.

THE VIEWS OF W. S. BRISTOWE

Bristowe in his latest paper (1938) separates the Archaedae from the other two sections of his Group Argiopoidea by erecting for it a separate Section B. He does not give any reasons for doing so, except for a few remarks on page 306, where he discusses their relationship to Symphytognathidae and Theridiidae. I shall discuss Bristowe's paper in another article dealing with the classification of spiders. It suffice to say here that Bristowe's opinion is not supported by any new evidence adduced by him and has, consequently, nothing to recommend it.

CHARACTERS OF THE KNOWN LIVING SPECIES OF ARCHAEA AND MECYSMAUCHENIUS

We now shall consider the characters of the known living species of Archaea and Mecysmauchenius, compare them with those of Landana

found in *L. petiti*, *L. cygnea* and *L. spinosa*, leaving the doubtful species of Landana out of consideration, and see at what conclusions we may arrive through such comparison.

The most conspicuous feature of Archaea is the peculiar development of the head, resulting in a considerable separation of the chelicerae from the mouthparts. This peculiarity reaches its climax in *A. workmanni* in which the head in both sexes is placed at right angles to the horizontal plane of the cephalothorax. (Fig. 10). It is so constricted in the middle that one is tempted to speak of this region as a "neck." Moreover, the total height of the head, measured from the margin of the carapace at the rostrum, is two and a half times as great as the total length measured from the same point to the posterior margin of the carapace. The head of the fossil species is not nearly as elevated as in *A. workmanni* and the "neck" is quite short and stout. The same is true of *A. hickmani*. In *A. godfreyi* a neck is apparently wanting and the head is only "almost 1½ times the whole basal length." The shape of the cephalothorax in *Mecysmauchenius segmentatus* may be best understood from the figures given by Simon and Canals. Compared with Archaea the head is but slightly elevated and at the same time projects forward. No measurements are given, but assuming the figures to be correct we may say that the height of the head measured as above is about equal to the length of the cepahlothorax measured from the anterior margin of the carapace at the rostrum to the posterior margin.

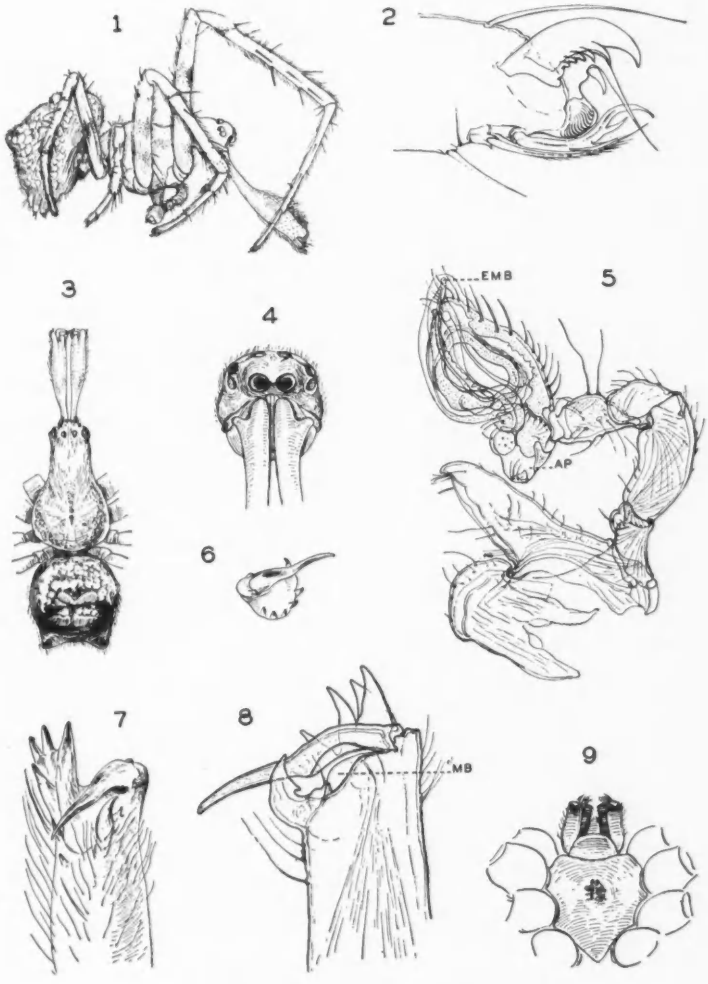
The shape of the cephalothorax in *Landana petiti* may be understood from the figure given by Simon. Here again measurements are wanting, but the head of the male is shown as considerably elevated above the thorax and at the same time considerably projected forward. Simon states that the head is longer than the thorax "partie céphalique plus longue que la partie thoracique" (1883, p. 185). This refers to the male. In 1907 Simon lists the species from the island of Fernando Poo, but gives no description and merely states that "L. Fea n'a receuilli que des femelles." The cephalothorax of *Landana cygnea*, male, is not figured, but described by Simon as follows: " . . . processu cephalico fere Landanae petiti E. Sim., sed paulo breviore et crassiore, cephalothorace haud longiore et antice oblique directo." (p. 329). The cephalothorax of the female is not described, except for coloration and the statement: "frons leviter prominens, haud producta." The shape of the cephalothorax of the male *Landana spinosa* may be best understood from figure 1. The head is somewhat longer than the thorax and but slightly raised above it. Thus we may state that the cephalothorax of Landana in the case of the male resembles more that of Mecysmauchenius than Archaea, but still undoubtedly belongs to the same type. We have an almost complete series of gradations from the extreme of the vertical head in *Archaea workmanni* to the extreme of the almost horizontal head in *Landana spinosa*.

An important feature of the carapace in all three genera is the presence of an anterior, transversely elliptic opening for the accommodation of the chelicerae. In the vast majority of spiders no such opening exists, the chelicerae being inserted just below the anterior margin of the carapace. In the process of moulting the carapace splits

off around its entire margin, while the old chelicerae remain attached to the ventral chitinous portion of the exuvium. How moulting takes place in such spiders as Archaea, Mecysmauchenius and Landana is not known, but evidently it cannot follow the general rule.

It must be pointed out that a separation of the chelicerae from the mouthparts occurs in some spiders, though not nearly to the same degree as in the genera under consideration. Simon gives a figure of the head of a male of an undescribed species of Argyroepeira (=Leucauge) from Ceylon (Hist. Nat., I, p. 732, f. 818). Among our common spiders the male *Linyphia clathrata* shows a somewhat similar condition (fig. 19). Although normally the chelicerae are held slantingly backward, so that their fangs occupy a position relative to the mouthparts identical with that of other spiders, their base is separated from the rostrum by a considerable distance. The opening for the reception of the chelicerae is of the same type as in Archaea, Mecysmauchenius and Landana, but the portion of the carapace between the chelicerae and the margin consists of much softer and lighter colored chitin. That portion is also much shorter than in the above genera, but the tendency to a separation between chelicerae and mouthparts is nevertheless clearly recognizable. The female does not present the same structure of the cephalothorax and like other Linyphiids of both sexes follows the type common to the majority of spiders.

The chelicerae of Archaea, Mecysmauchenius and Landana are without boss, but so are the chelicerae of many spiders and there is a difference in this respect even within the family Argiopidae, some groups possessing and others lacking or having only a rudimentary boss. The articulation of the chelicerae with the head is of the same type in *Archaea workmanni* and *Landana spinosa*. It differs from that of other spiders in that it permits very considerable up and down motion due to the constriction of the chelicera at its base and to the presence of an articulating condyle. The armature of the chelicerae is different in Archaea and Landana, while Mecysmauchenius is in this respect more like Archaea than Landana. But the armature in Landana differs also considerably from all spiders comprised in Simon's family Argiopidae. The length of the basal joint of the chelicerae in *Archaea workmanni* is more than twice as long as the carapace if the latter is measured from its anterior margin just above the rostrum to the posterior margin, but less than the total height of the head. In *Archaea godfreyi* it is almost the same as the height of the head and therefore somewhat less than 1½ times the length of the carapace. In Mecysmauchenius the basal joint of chelicerae according to Simon is shorter than the cephalothorax when the latter is measured from the anterior end of the head to the posterior margin of the carapace in the usual manner. Judging from his figure showing the cephalothorax in side view we may say that the basal joint of chelicerae is almost, but not quite as long as the carapace when the latter is measured in the manner given here for *A. workmanni*. This is also supported by the excellent figure of the spider given in the paper of Canals. In *Landana spinosa* the basal joint of chelicerae is slightly longer than the total length of the cephalothorax, i. e., relatively much longer than in Mecysmauchenius and about as long as in *A. workmanni*. The chelicerae of *Archaea godfreyi*, according to Hewitt,



Landana spinosa n. sp. Type

Fig. 1. Lateral view of male. 2. End of third tarsus. 3. Dorsal view of male. 4. Face of male. 5. Palp of male. 6. End-view of chelicera. 7. Ventral view of chelicera. 8. Prolateral view of chelicera. 9. Sternum.

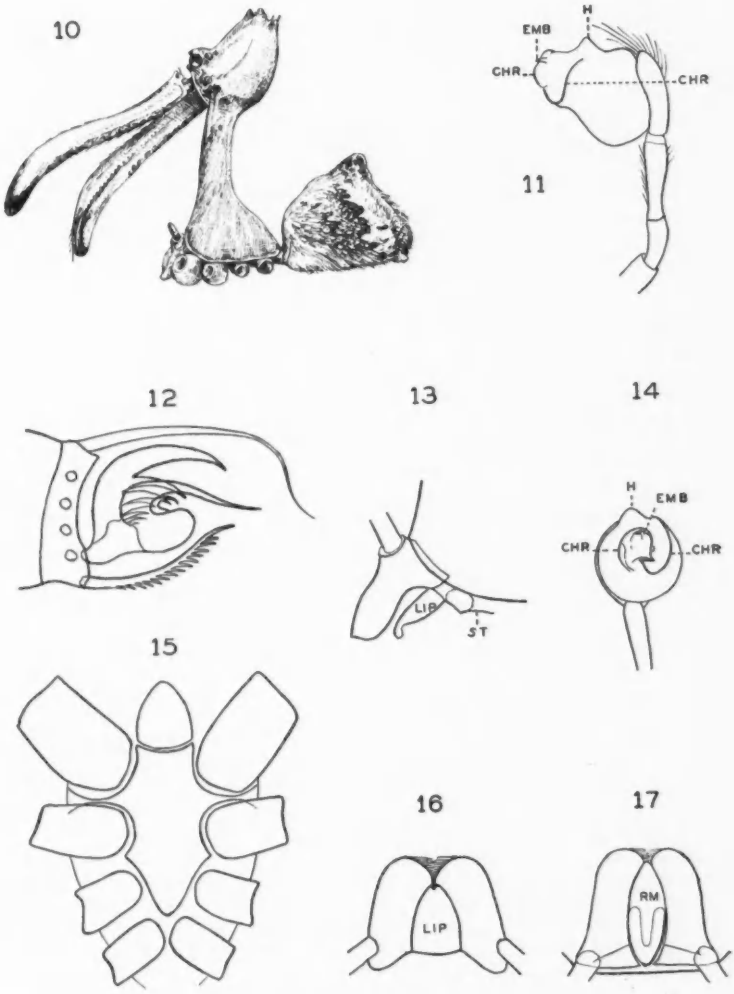
AP—Apophysis; EMB—Embolus; MD—Membrane.

possess on their outer surface a series of close-set parallel ridges which may be part of a stridulatory apparatus. None of the other species of Archaea show anything of the kind, nor do Mecysmauchenius or Landana. We know similar organs in the Linyphiidae.

The shape of the maxillae is always difficult of description. Usually they are studied in a ventral view in conjunction with the lip. All references to their shape are based on such study. It is due to this that the maxillae of Archaea and the attachment of the palp are wrongly interpreted. Simon's figure 1006 on page 935 of the first volume of his Histoire Naturelle des Araignées is altogether misleading. In *Archaea workmanni* the base of the lip is not straight but procurved and the maxillae do not touch each other except at the point nearest the lip (Fig. 16). In this position the palpi appear arising from the outer sides of the maxillae near their base. A similar picture is obtained when one views the maxillae from in front (Fig. 17). Owing to a somewhat greater length of this surface and owing to the fact that not only the anterior ends, but the inner angle of the base of the maxillae are in contact with each other, the general impression is that the maxillae are but slightly inclined toward each other. When one examines the maxillae in side view (Fig. 13) they appear as organs of almost the same thickness as their width. The attachment of the palp is on the anterior edge and not in the middle of the lateral surface. That is why use was made in analytical keys of this character as one separating them from other spiders. But this is decidedly wrong. Not only is there no important morphological difference between a median and a dorsal lateral attachment of the palp, but we find all gradations between these two positions in other spiders. Thus the attachment of the palp is of the same type in *Landana spinosa* and in *Linyphia clathrata*.

Simon mentions the presence of a fine serrula among other characters of the family Archaeidae. This is not quite correct. Neither an examination under a binocular microscope at a magnification of 75 diameters, nor a study of serial sections at still higher power reveals any trace of a serrula in *Archaea workmanni*, the only species known to Simon. On the other hand much later a serrula has been described in *A. godfreyi* and *A. hickmani*. In *Landana spinosa* the serrula is wanting. Neither does Simon mention the serrula in his description of the species of Landana discovered by him.

The lip in *Archaea workmanni* is longer than wide, narrowed gradually toward the tip. The tip is thickened and the lip should be therefore properly termed as being rebordered and not flat. The difference from a typically rebordered lip is of a subordinate character, namely that instead of being thickened over its entire width, the thickening is restricted to the tip. It is clearly visible in sideview (Fig. 13). The lip of *A. hickmanni* is described as being "short" (p. 48), while that of *A.* godfreyi is figured as long as broad. What Hewitt describes as "apex distinctly incised" is probably nothing but an optical illusion, the apical thickening appearing as an incision because of the clear outline of the edges. In *A. workmanni* the lip has also the appearance of an incision when examined in artificial light, until one finds the proper angle of illumination and uses higher power. The lip of Landana is



Archaea workmanni (O. P. Cambridge)

Fig. 10. Lateral view of male 11. Retrolateral view of left palp. 12. End of third tarsus. 13. Lateral view of maxilla and lip. 14. Ventral view of palp. 15. Sternum. 16. Ventral view of maxillae and lip. 17. Dorsal view of maxillae and rostrum.

CHR—Chitinous ridge; EMB—Embolus; H—Hump; LIP—Lip; RM—Rostrum; ST—Sternum.

wider than long and very slightly rebordered along its entire anterior edge. The lip of Mecysmauchenius is described by Simon as being wider than long; "pars labialis latior ad basin quam longior." (1883, p. 377).

The sternum of *A. workmanni* is much longer than wide. The figure given by Hewitt shows that in *A. godfreyi* it is also much longer than wide. For *A. hickmanni* Butler states that the sternum is "longer than broad." (p. 48.) According to Simon the sternum in Mecysmauchenius is nearly twice as long as wide. In this respect *Landana spinosa* is different, for its sternum is as wide as long.

The legs do not always follow the same order of sequence. In *A. workmanni* and *Landana spinosa* the order is 1243. In *Archaea godfreyi* and *A. hickmanni* it is 1423. In Mecysmauchenius the order in the female is 4123, in the male 1423. The legs in Archaea and Landana are long and slender, those in Mecysmauchenius much less so. The legs of all Archaea and Mecysmauchenius are devoid of true spines, but in Mecysmauchenius the posterior metatarsi according to Simon are "inferne valde setulosis et subspinosis." The legs of Landana have numerous spines. But this difference is not of great importance. We have examples in other families where some genera have spines and others are devoid of them. Moreover, the distal third of the third and fourth metatarsi in *A. workmanni* may be also best described as being sub-spinose, because they have numerous ventral serrated bristles of considerable size.

Simon's statement that auxiliary claws in Archaea are wanting is not correct. Examination under immersion oil at very high power reveals the presence in *A. workmanni* of a pair of serrated bristles which have all the appearance of spurious claws except that they possess numerous serrations. (Fig. 12). Landana has serrated bristles of the same type and in addition a pair with fewer serrations. (Fig. 2).

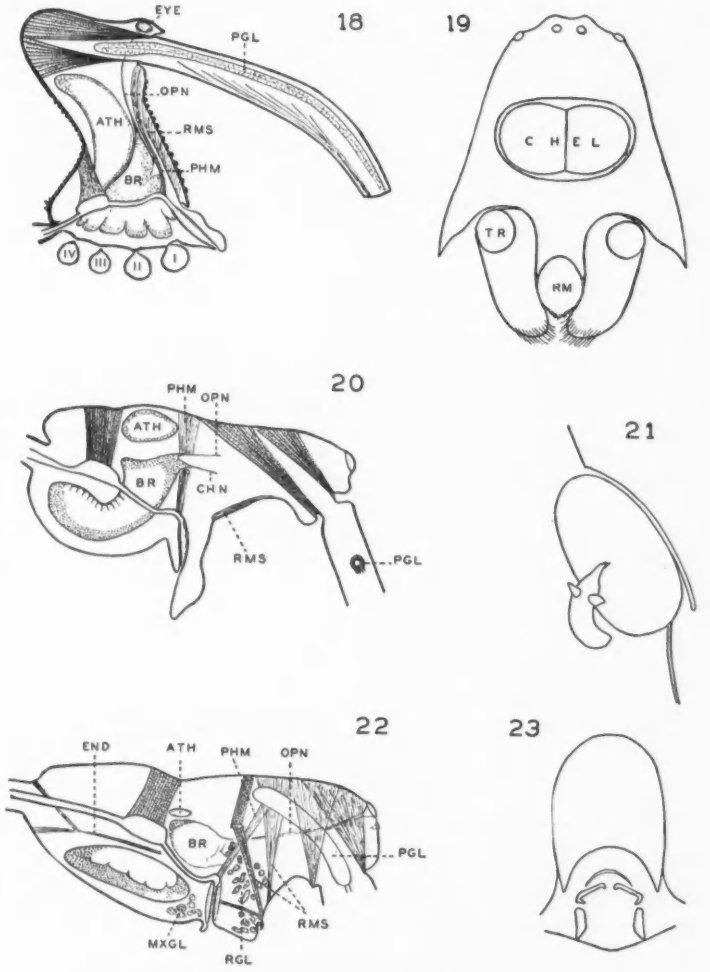
Simon's statement that the spinnerets of Archaea are very characteristic I cannot understand. As he himself states the anterior pair resembles those of other Argiopidae. The posterior spinnerets are indeed much more slender, but otherwise quite normal in appearance. Of course, Mecysmauchenius has only two spinnerets.

The structure of the claws and the distribution of trichobothria is the same in *Archaea workmanni* and *Landana spinosa*.

The structure of the male palp is known in both species of Mecysmauchenius, in *Archaea godfreyi* and in two species of Landana. I give below a description and figures of the palp in *Archaea workmanni* and *Landana spinosa*. It is generally admitted that the trochanter of the palp is unusually long in Archaea. This is true in a sense, inasmuch as it has the appearance of a considerably longer segment than is usual in spiders. But if one examines the trochanter in its relation to the femur, the condition found in Landana approaches that of Archaea.

EXPLANATION OF ABBREVIATIONS FOR FIGURES 18–23

ATH—Anterior thoracenteron; BR—Brain; CHN—Cheliceral Nerve; END—Endosternite; MXGL—Maxillary gland; OPN—Optic nerve; PGL—Poison gland; PHM—Pharyngeal muscle; RGL—Rostral gland; RMS—Rostral muscle; TR—Trochanter.



Figs. 18, 21 and 23. *Archaea workmanni* (O. P. Cambridge).
Figs. 19 and 22, *Linyphia clathrata* Sundevall.
Fig. 20, *Landana spinosa* n. sp. Type.

Fig. 18. Composite drawing of a longitudinal section through the cephalothorax of Archaea. 19. Front view of the head of *Linyphia clathrata*. 20. Composite drawing of a longitudinal section through the cephalothorax of Landana. 21. Lateral view of epigynum of Archaea. The big oval shows the outline of what appears as a transparent vesicle. 22. Composite drawing of a longitudinal section through the cephalothorax of Linyphia. 23. Ventral view of the epigynum of Archaea. The two central hooks are strongly chitinized.

The cymbium varies in all species. In Archaea it lacks an apophysis. In Mecysmauchenius a pointed apophysis is present. In Landana the apophysis is broad and especially large in Landana spinosa. The bulb shows many features in common in all species of Archaea, Mecysmauchenius and Landana.

The eyes are always subject to variation is spiders. Archaea has eight eyes, the anterior median eyes being by far the largest and alone of the diurnal type. The same is true of Landana. The only difference is that in Archaea these eyes are far apart, while in Landana they are much closer together, a condition of generic, but certainly not of family value. Mecysmauchenius has only six eyes, the anterior median pair wanting.

EVIDENCE FROM INTERNAL STRUCTURES

The internal anatomy is known only in as far as I have reported in 1933 from my own studies on an immature female of *Archaea workmanni*. Since that time I have sectioned and studied another specimen of the same species and a mature male *Landana spinosa*.

The heart in both *Archaea workmanni* and *Landana spinosa* has three pairs of ostia.

The tracheal system in *Archaea workmanni* seems to be wanting. At least I am unable to find on any section a single one through a tracheal tube. Nor is it possible to detect any spiracular opening. For Mecysmauchenius Simon states that the spiracle is situated a little in advance of the spinnerets, but he does not give any information concerning the tracheal system itself. In *Landana spinosa* the tracheal spiracle is situated immediately in front of the spinnerets. It leads into a small atrium from which two tracheal stems arise. Each of these forms almost immediately a pair of tubes. Thus four simple tubes are present in the abdomen. None enter the cephalothorax.

The poison glands of Archaea are almost entirely endocheliceral. (fig. 18.) The duct is restricted to the fang. The gland extends somewhat into the head, about half way between the cheliceral foramen and the posterior wall of the head. It does not extend into the neck. In Landana (fig. 20) the poison gland is entirely endocheliceral. It ends shortly before the cheliceral foramen of the head. The duct is restricted to the fang. In Argiopidae, Linyphiidae and Theridiidae the gland is endocephalic, as far as we know. (fig. 22.)

The digestive system of Arachaea begins with a spacious and long pharynx which extends to the base of the rostrum. The oesophagus shows the usual sigmoid bend. The pumping stomach is situated in the region between the third and fourth pairs of coxae and the dorsal muscle is attached to the posterior (morphologically dorsal) wall of the thorax, just below the neck. The most remarkable feature of the thoracenteron is the powerful dorso-median blind sack (fig. 18, ath.) extending into the neck behind the nervous system all the way to the cheliceral muscles. In Landana the pharynx is of the same type and ends at the base of the rostrum. The dorsal muscle of the pumping stomach is attached to the dorsal wall of the thorax just behind the slight dorsal groove. The dorsal median blind sack of the thoracenteron is present and large, but on account of the shape of the cephalothorax it is shorter than in

Archaea, the cheliceral muscles extending almost over the entire length of the head. (fig. 20, ath.)

On account of the direction chosen for sectioning the abdomen, the structure of the chylenteron cannot be safely determined in either species. The white pattern is due both in Archaea and in Landana to subcutaneous guanin cells, but the latter are more developed in Landana than in Archaea.

The maxillary glands in Archaea are large, multicellular and open at the tip of the maxillae without a sieve. Landana also has no sieve and the large, multicellular maxillary gland opens to the outside in the same, rather unusual manner as in Archaea by a single duct at the tip of the maxilla.

On account of the shape of the cephalothorax the nervous system in Archaea has a very peculiar shape. (fig. 18.) The brain is drawn out vertically and the optic nerves are of an extraordinary length, unlike anything in other spiders. The thoracic ganglionic mass is composed of twelve neuromeres. As in other spiders studied by ordinary staining methods no trace of any nerves can be seen in the abdomen. The brain of Landana (fig. 20) has at first sight a different appearance, but in reality closely follows that of Archaea inasmuch as it, too, is drawn out, but forward instead of upward, and the optic nerves are very long. The thoracic mass is clearly composed of twelve neuromeres and no trace can be found of nerves in the abdomen.

The coxal glands are typical in both Archaea and Landana, as one would naturally expect them to be. There is a single duct to the outside behind the coxa of the first leg.

The study of the spinning glands requires dissection rather than sectioning. For this reason I am unable to give any information on the subject, which would be of interest from the point of view of comparative anatomy.

The muscular system of the cephalothorax presents some interesting peculiarities on account of the unusual development of the head. The dorsal muscle of the pumping stomach is attached normally as in all spiders to the dorsal wall of the thorax just behind the head. The dorsal pharyngeal muscle in *Archaea workmanni* is inserted in the pharynx in the usual place but its other end is attached not to the dorsal, but to the anterior, i. e., morphologically ventral surface immediately under the attachment of the depressor of the chelicera. In Landana the dorsal pharyngeal muscle runs straight upward to the dorsal wall of the carapace and is attached behind the dorsal attachment of the depressor of the chelicera. The same is true of *Linyphia clathrata*, except that here the pharyngeal muscle runs obliquely forward. The depressor inserted into the rostrum on the dorsal surface near its articulation with the carapace has the appearance of a feather in *Archaea workmanni*, the "shaft" running anteriorly to the dorsal pharyngeal muscle and the "barbs" attached all along the anterior surface of the carapace. In Landana the corresponding muscle has the same point of insertion in the rostrum. It has the usual appearance of a muscle and the fibres are inserted into the ventral wall of the carapace behind the insertion of the depressor chelicerae. In Linyphia (fig. 22)

this muscle is wanting. Instead there are two muscles, both running dorsally. The first is inserted on the anterior surface of the rostrum at its base and its dorsal fan-shaped attachment is just behind the depressor chelicerae and to the outside of the dorsal pharyngeal muscle. The second muscle is inserted into the rostrum just in front of the opening of the rostral gland. It arises from a dorso-lateral apophysis of the endosternite. These two muscles undoubtedly act as dilators of the pharynx by lifting the rostrum upwards. On the other hand the rostral muscle in Archaea and Landana can work only as a depressor, lowering the tip of the rostrum over the end of the lip and thus closing the mouth.

Perhaps the greatest difference between *Linyphia clathrata* on the one hand and Archaea and Landana on the other, is in the extraordinary development of the rostral and maxillary glands in the former. Whereas both glands are restricted to the corresponding portions of the body in Archaea and Landana, in *Linyphia clathrata* (fig. 22) both glands extend into the body proper. Sections of the maxillary glands appear behind the lip and the rostral gland occupies a large portion of the space above the rostrum and in front of the brain. However, in this respect Linyphia is rather an exception and not Landana and Archaea.

Concerning the habits of Archaea we have no information of any kind. The only statement is that of Mr. Godfrey on the South African species *Archaea godfreyi*, as reported by him to Mr. Hewitt. Godfrey "found a single specimen under a stone in the damp bush above Fern Kloof, Grahamstown." Neither do we know anything about the habits of Mecysmauchenius. Of *Landana cygnea* Simon writes: "Le *Landana cygnea* E. Sim., que j'ai observé dans la forêt de San-Esteban, au Venezuela, file une toile semblable á celle d'un *Meta*, parfaitement normale, mais assez petite et accompagnée d'un tube suspendu á ses côtés et communiquant avec son centre par un fil conducteur. Ce tube, qui sert de retraite et recoit les cocons au moment de la ponte, est recouvert de petites bùchettes, peu régulières, se dissociant au moindre contact, il rapelle celui du *Theridion riparium* Bl. ou plus exactement le fourreau de quelques larves de Phryganes." (Hist. Nat. Ar., I, p. 733). The males of *Landana spinosa*, which I collected in Barro Colorado, were found in a small web about five feet above the ground. The web was made of irregular threads, not in the shape of an orbweb, but the spiders reminded me of *Uloborus cinereus* Cambridge which is common on the island and for which I mistook them before I had a chance to examine them under a binocular in the laboratory.

SUMMARY OF RECENT EVIDENCE ON RELATIONSHIPS WITHIN THE ARCHAEIDAE

In summing up the results of this investigation we are driven to the conclusion that Landana is more closely related to Archaea than either to Meta or to Linyphia, that the only tangible characters separating both Landana and Archaea from Argiopids and Linyphiids are the considerable distance between the rostrum and the chelicerae, the absence of a maxillary sieve, the restriction of the poison glands to the chelicerae (endocheliceral) and the possession of a musculus depressor rostri. All other characters they either share with Argiopids and

Linyphiids or at least possess them in such slight modifications as to make them quite useless for separation. This is a conclusion very different from the one arrived at by Koch and later by Simon and in direct contradiction with Bristowe's latest classification, who tries to establish a quite incongruous Group VIII Argiopoidea composed of three sections: A—Symphytognathidae; B—Archaeidae; and C—Theridiidae, Linyphiidae, Tetragnathidae, Argiopidae and Mimetidae. I shall not discuss here the impossibility of including the Symphytognathidae in this group, but I wish to point out that the Section B—Archaeidae cannot be maintained and if the family can be retained as such, it must be placed in the vicinity of the Linyphiidae and Argiopidae as being closely related to both, but especially to the former.

Family **Archaeidae**

Spiders with diaxial chelicerae, one pair of lungs, tracheal system restricted to the abdomen or wanting, three pairs of cardiac ostia and three tarsal claws. Head either elevated or produced forward, supplied with a foramen for the reception of the chelicerae. Chelicerae without boss, separated from the rostrum by a considerable distance. Eight eyes in two rows, heterogeneous, anterior median pair alone diurnal, or only six nocturnal eyes, the anterior pair wanting. Maxillae more or less inclined over lip, with or without a serrula, with a weak scopula. Sieve wanting, opening of maxillary glands at tip of maxilla. Lip free, slightly rebordered. Sternum longer than wide or at least as long as wide, pointed behind. Legs fairly long and slender. Upper claws pectinate in a single row. Third claw long, slender, with a single basal tooth. Serrated bristles present. Trichobothria few, in two rows on tibiae, a single trichobothrium on metatarsus. Abdomen soft, variable in shape. Tracheal spiracle close to spinnerets or wanting. Six or two spinnerets.

KEY TO SUBFAMILIES AND GENERA

1. Eight eyes. Six spinnerets. 1 Subfamily **Archaeinae** 2
   Six eyes. Two spinnerets. 2 Subfamily **Mecysmaucheniinae.**
   A single Genus ..... **Mecysmauchenius**
2. Head elevated. Legs without spines. 1 Genus ..... **Archaea**
   Head produced forward. Legs with numerous spines. 2 Genus ..... **Landana**

Genus **Archaea** Koch and Berendt, 1854

Type: *Archaea paradoxa* Koch and Berendt

KEY TO SPECIES

1. Recent species 2
   Fossil species from Baltic Amber 4
2. Legs 1243. Head strongly constricted, forming a thin neck. Vertical axis of cephalothorax two and one-half times as long as longitudinal horizontal axis. Top of head with two pairs of tubercles. Chelicerae long, slender, strongly constricted at base, diverging and bent downward in distal quarter. Abdomen high, almost triangular in side view. Male and immature females much alike. Male palp as figured (Figs. 11, 14).
   Madagascar ..... **Archaea workmanni** (O. P. Cambridge)
   Legs 1423. Neck much stouter. Vertical axis not more than one and a half times as long as horizontal axis 3

3. Female. Male unknown. Forehead with convex protuberance each side. Chelicerae without stridulatory ridges. Sternum and carapace smooth. Australia.....**Archaea hickmani** Butler
   Male. Female unknown. Forehead without protuberances. Chelicerae with stridulatory ridges. Sternum and carapace granular. South Africa.....**Archaea godfreyi** Hewitt
4. Head hemisphaerical, without neck. Eyes not much elevated. Abdomen almost globular, with parallel grooves, with hair. Chelicerae moderately long. Legs densely covered with curved hairs. Sex not mentioned, **Archaea hyperoptica** Menge
   Head with a distinct constriction forming a short neck..... 5
5. Head with two posterior angular projections. Abdomen with a pair of dorsal humps and posteriorly projecting beyond the spinnerets. Chelicerae comparatively short. Presumably a female, **Archaea conica** Koch and Berendt
   Head rounded, without angular projections. Abdomen not projecting beyond the spinnerets. Chelicerae relatively long..... 6
6. Abdomen egg-shaped or almost globular..... 7
   Abdomen laterally compressed, with parallel furrows. Carapace granular. Chelicerae very long, strongly diverging. Males more slender than females.....**Archaea paradoxa** Koch and Berendt
7. Abdomen smooth..... 8
   Abdomen with parallel furrows..... 9
8. Head rounded, globular. Carapace smooth. Chelicerae twice as long as the head, without teeth, only with fine bristles. Sex uncertain. Abdomen egg-shaped.....**Archaea laevigata** Koch and Berendt
   Head longer than wide. Carapace slightly wrinkled. Chelicerae more than twice as long as head, with numerous spines. Abdomen globose. Female.....**Archaea pougneti** Simon
9. Abdomen with parallel furrows its full length. Carapace with isolated tubercles. Females.....**Archaea incomta** Menge
   Parallel furrows only in the posterior region of the abdomen. Carapace with granules arranged in rows forming a network. Females, **Archaea sphinx** Menge

Archaea workmanni (O. P. Cambridge)

Male, androtype. (Figures 10–18, 21, 23.)

Total length from tips of maxillae to end of abdomen 5.16 mm.
Length of carapace from anterior to posterior margin 1.97 mm.
Height of carapace from base to end of head 5.16 mm.
Length of basal joint of chelicerae 4.64 mm.
Length of fang 0.93 mm.
Length of abdomen from petiolus to end of spinnerets 2.45 mm.
Height of abdomen in a straight line from venter to tip of dorsal protuberance 2.32 mm.
Width of neck anteroposteriorly in narrowest place 0.58 mm.
Ratio of eyes AME : ALE : PME : PLE = 7 : 2.5 : 2.5 : 2.5.
AME separated from each other by 36/7 of their diameter, i. e., by slightly more than five times their diameter, and from the ALE by 10/7 of their diameter.
AME separated from PME by 6/7 of their diameter.
Quadrangle much wider than long, wider in front than behind in the ratio 42 : 30.
Lateral eyes contiguous, situated considerably below the median eyes.
AME on prominent tubercles and alone diurnal, black.
Lateral eyes on each side on a joint, very small tubercle, nocturnal, white.

PME sessile, nocturnal, white.

Eyegroup occupies entire width of the head proper. Both eyelines are curved downward. On account of the shape of the head it is impossible to determine whether the lines are procurved, or recurved.

On the top of the head two pairs of coneshaped tubercles, the anterior pair twice as far apart as the posterior pair. The latter with a small terminal, articulated, cylindrical segment (sense organ?).

The chitin of the carapace is smooth, light rufous, clothed sparsely with spatulate, white hairs. The foramen for the reception of the chelicerae is much larger than the diameter of the basal, constricted portion of the latter.

Chelicerae strongly constricted at base, this portion having only half the diameter of the succeeding portion. A small dorsal, coneshaped projection at the base of the latter. The chelicerae are strongly diverging, bent downward in distal quarter. The margins proper, i. e., the chitinous edge of the joint, are short and form together a parabolic curve. Proximal to the promargin is a row of 10 bristles extending as far as the end of the fang when the latter is fully flexed. Beyond this point and reaching as far as the middle of the chelicera is a row of short, heavy spines, decreasing in length proximally. The retromargin is with 5 small teeth followed by a gap and then by a row of 4 short spines, the first of which is situated at the point where the folded fang ends, the fourth at the point where the basal joint is bent downward. The fang is bent, slightly sinuous and serrated along its entire edge.

Rostrum almost as long as maxillae, pointed at both ends.

Maxillae almost as thick as wide in front (above) and behind (below), with rounded ends and a small, sharply pointed projection on which the duct of the maxillary gland opens. They are therefore in close contact with both the rostrum and the lip. They almost meet in the median line at the end of the rostrum and the lip; the space between the diverging, curved anterior edge is occupied by the sparsely developed maxillary scopula. A serrula is completely wanting and is not represented even by a smooth ridge of the type found in some spiders. The trochanter of the palp is inserted on the outer edge of the maxilla, near its base, in the angle formed by the anterior and lateral surfaces.

Lip free, longer than wide, pointed and slightly rebordered in front, with somewhat procurved base and curved sides.

Sternum longer than wide in ratio 36 : 21, pointed behind in front of the fourth coxae which it does not reach. Laterally the sternum is produced between first and second and second and third pairs of coxae and is connected with the carapace by a narrow chitinous bridge between first and second coxae, but not between second and third.

First coxae separated by the width of the lip, fourth coxae contiguous. There is a distinct space separating each coxa of the same side from the following one. First and second coxae much heavier than third and fourth. First coxa twice as heavy and twice as long as fourth coxa.

Legs 1243.

	Femur	Pat.+ Tibia	Metatarsus	Tarsus	Total
I.....	7.41	8.36	3.80	0.90	20.47
II.....	4.37	4.75	1.71	0.66	11.49
III.....	2.85	2.85	0.90	0.57	7.17
IV.....	3.42	3.42	1.14	0.57	8.55

Palp—Trochanter 0.40, Femur 0.95, Patella 0.38, Tibia 0.38, Cymbium 0.45, Bulb 0.69 long, 0.50 wide.

All femora nearly twice as wide at base as in middle, the respective measurements for the first femur 0.333 and 0.167 and for the fourth 0.214 and 0.119. Tibial index I—3, II—4.7, III—7.5, IV—5.9.

No true spines on legs, but numerous serrated bristles under the third metatarsus and under the fourth in its distal third. Trichobothria on tibiae 1–1–2 (the pair not quite opposite each other) and on metatarsi a single one. Three claws on a small onychium. Upper claws curved, with six teeth in proximal half, increasing in length distally. Third claw curved, thin and long, with a single curved tooth at base. Two pairs of strongly serrated bristles on the onychium under the claws. The other four pairs of bristles situated on the sides and above the onychium have only fine serrations.

The palp as shown in figures 11 and 14. Viewed from below the bulb is almost circular with two chitinous ridges, one near middle forming almost a horseshoe, the other passing in a curve to the outside surface on which it continues to the base of the dorsal hump. The embolus is very small, thornlike, at the end of the bulb.

Abdomen flat below, rising in a curve dorsally and forming a coneshaped protuberance, descending hence in a steep sigmoid curve to the spinnerets. Six spinnerets. Anterior pair heaviest, contiguous, coneshaped with hemispherical terminal joint. Median pair very small. Posterior pair slender, cylindrical, far apart at base but touching each other with the ends of their short terminal joint. Colulus wanting. The spinnerets form with the anal tubercle a circle. Tracheal spiracle wanting.

Integuments clothed with white, short, spatulate hairs.

Color in alcohol: carapace, maxillae, lip and sternum, light rufous. Chelicerae sprinkled with brown. Legs almost white. Abdomen very light yellow with brown markings on sides.

The female which I believe to be in the penultimate instar, is of the same size as the male. The chelicerae are quite as long, the head has the same shape, the abdomen somewhat heavier on account of the developing eggs, the legs in the same order, but slightly shorter. The epigynal region (figures 21 and 23) shows a large thin-walled, translucent sac of more or less ellipsoidal shape, with a peculiar projecting scape the interpretation of which is very difficult. On sections both the scape and the sac appear to be hollow. In the wall of the sac, nearest the abdominal wall the openings of the reproductive ducts presumably those of the receptacles. The eggs are still immature.

Genus **Mecysmauchenius** Simon, 1883

Type *M. segmentatus* Simon

KEY TO SPECIES

1. Abdomen with dark, oblique markings. Male palp with tibial apophysis. Apophysis of cymbium nearer middle, with but slightly curved spine. Epigynum more or less rectangular, without scape. Chile: Magallanes, Islas Juan Fernàndez. Argentina: Tierra del Fuego, Lago Nahuel Huapí.....**Mecysmauchenius segmentatus** Simon

   Abdomen without markings. Male palp without tibial apophysis. Apophysis of cymbium nearer base, with strongly curved spine. Epigynum semicircular, with a narrow, long scape above. Chile: Magallanes.....**Mecysmauchenius nordenskjöldi** Tullgren

Genus **Landana** Simon, 1883

Type *L. petiti* Simon

KEY TO SPECIES

(a) Males.

1. Head obliquely considerably raised, longer than thoracic portion. Cheliceral retromarginal process with three teeth, promargin with a single tooth. Congo.....**Landana petiti** Simon

   Head flatter. Retromarginal process with more than three teeth..... 2

2. Retromarginal process of chelicerae with four teeth, promargin with three teeth. Legs with three dark rings. Cymbium with basal apophysis obtusely quadrate and slightly emarginate. Venezuela, **Landana cygnea** Simon

   Retromarginal process with five teeth, a sixth tooth lower down. Promargin with two teeth of which the proximal one is much larger, curved and supplied with a small auxilliary tooth of its own. Basal apophysis of cymbium very large, subquadrate, with three lobes. Legs without dark rings. Panama.....**Landana spinosa** n. sp.

(b) Females.

1. Size larger, 9 mm. AME not much larger than the others. Species of doubtful generic affiliation. Chile.....**L. edwardsi** Simon

   Size smaller, 4.5 mm. AME at least twice as large as the others. Retromargin of chelicerae with four teeth and a fifth one at a considerable distance nearer proximal end. Promargin with three large teeth. Venezuela.....**Landana cygnea** Simon

(*Landana lautiuscula* Dalmas, from New Zealand, does not belong to the genus Landana.)

Landana spinosa n. sp.

(Figures 1–9, and 20)

Male. Type. Total length without chelicerae, from posterior abdominal humps to anterior end of cephalothorax 3.13 mm. Carapace 1.80 mm. long, 0.57 mm. wide in the middle of the head, 1.13 mm. wide between second and third coxae, where it is widest. The thoracic portion is almost circular. The head is with almost parallel sides, slightly bulging in middle. Thoracic groove wanting, but a deep depression beginning in middle of thoracic portion extends backward gradually widening until it reaches posterior margin which it fully occupies.

Head in direct continuation with and only slightly and quite gradually raised above the thorax, somewhat longer than the latter and thickened toward end to accommodate the chelicerae.

Eight eyes in two rows, heterogeneous, AME alone diurnal, directed forward and by far the largest. The two rows are equal in length and the lateral eyes are contiguous. Viewed from above the first row is strongly recurved, the second row so slightly recurved that it may be said to be straight. Full width of eye group 0.48 mm.

Ratio of eyes AME : ALE : PME : PLE=5 : 3 : 3 : 3.

AME separated from each other by 1/5 of their diameter and from the ALE by 3/5 of their diameter. PME separated from each other by 2.5/5 of the diameter of the AME, or by a little less than their own diameter. PME separated from PLE by 4.5/5 of the diameter of the AME, or by one and one-half of their own diameter.

Quadrangle of medians wider in front than behind in ratio 11 : 9, longer than wide in front in ratio 13 : 11.

All eyes are set in narrow black rings. Clypeus almost wanting.

Chelicerae with a basal, retrolateral condyle, (fig. 4) inserted in a foramen situated directly under the AME and therefore at a considerable distance from the rostrum. They are parallel to each other for their entire length. Basal joint 1.80 mm. long from base to the point of articulation with the fang, or 1.90 mm. to the end of the retrolateral apophysis. The proximal half of the basal joint is much thinner than the distal half and is distinctly curved, so that its anterior surface appears to be longitudinally concave. The distal half is with parallel sides and ends in a retrolateral (ventral by position) apophysis supplied with five teeth, a sixth tooth situated lower down. The promargin has two teeth of which the one nearest the base of the fang is small, coneshaped and simple, the proximal one (fig. 8) very large, curved and supplied with a small tooth of its own. A peculiar membrane or flap is situated between the margins and fits snugly into a corresponding emargination of the fang. It seems probable that this is a preening apparatus for the palpi which all spiders clean by passing them under the fang. The fang is short, only 0.048 mm. from articulation to tip in a straight line. It is distinctly sinuous and its ventral surface presents two edges, one of which is more or less normal, while the other is excavated for the reception of the membrane mentioned above. From the end of this excavation to the end of the fang the edge is minutely serrated. The poison duct opens terminally. There is no stridulating apparatus on the chelicerae.

The rostrum is very long so that it overhangs the mouth considerably.

The lip is free, but its base is strongly procurved. It is wider than long, with rounded end very slightly rebordered. The lip is hinged to the maxillae by means of a socket fitting into a condylus arising from the middle of the inner edge of the maxilla. The end of the lip does not reach the middle of the visible length of the maxillae.

Maxillae with almost parallel sides and but slightly inclined over the lip. A small ventral thorn is situated at the end. This is the point at which the duct of the maxillary gland opens. A sieve as well as a serrula is wanting. The scopula covers the end and the distal half of inner edge and is composed of serrated hairs.

Sternum shield shaped, as wide as long, emarginate in front, pointed behind between the hind coxae.

First and second coxae much heavier and longer than third and fourth coxae. First coxae wide apart, fourth coxae separated by half their width.

Legs 1243.

	Femur	Pat.+ Tibia	Metatarsus	Tarsus	Total
I	2.34	2.49	1.74	0.78	7.35
II	1.80	1.95	1.20	0.60	5.55
III	0.96	0.99	0.60	0.36	2.91
IV	1.44	1.29	0.84	0.42	3.99

Palp: Trochanter ventral 0.128, dorsal 0.176; Femur ventral 0.256, dorsal 0.368; Patella ventral 0.090, dorsal 0.184; Tibia ventral 0.240, dorsal 0.160; Cymbium 0.520, Total dorsal with trochanter 1.408.

Spines. *First leg*. Femur dorsal 0–1–0, prolateral 0–1–1, retrolateral 0–1–1, ventral 0. Patella dorsal 0–1, elsewhere 0. Tibia dorsal 1–0–1, prolateral 1–1–1, retrolateral 1–1–1, ventral 0–1–1. Metatarsus dorsal 1 small spine near base, prolateral 1–1, retrolateral 1–1, ventral 1–1–0. Tarsus 0. *Second leg* same as first except Femur ventral 1–1–1, Tibia prolateral 1–0–1, retrolateral 1–0–1, Metatarsus retrolateral 1–0, ventral 1–1–1. *Third leg* . Femur dorsal 0–1–1, prolateral 0–0–1, retrolateral 0–0–1, ventral 1–1–0. Patella dorsal 1–1, the first a bristle, Elsewhere 0. Tibia dorsal 0, prolateral 0–1–0, retrolateral 1–0–0, ventral 0–1–0. Metatarsus dorsal 1 large spine near base, prolateral 1–0, retrolateral 0, ventral 1–0–0. Tarsus 0. *Fourth leg* same as third except Femur prolateral 0–1–1, ventral 0. Tibia dorsal 1–0–1, prolateral 0–1–1, retrolateral 0–0–1, ventral 0–1–1.

Trichobothria. *First leg*. Femur 0, Patella 0, Tibia 2–2–2 in proximal half, Metartasus 1 about 1/5 from base. Tarsus 0. *Second leg* same as first. *Third leg* same as first, but the trichobothria are of unequal length, the three retrolateral ones increase in length distally, the second being twice and the third three times as long as the first. Of the prolateral trichobothria only two are present and the distal one is of an extraordinary length and stoutness, longer than the retrolateral spine and stouter than the common hair. *Fourth leg* same as third on tibia, but no trichobothria elsewhere.

A "drum" is present on all tarsi. On the first tarsus it is beyond the middle, on the second in the middle, on the third and fourth behind the middle.

Onychium wanting, but behind serrated bristles a line suggests its presence. (fig. 2). Three claws. Upper claws slightly dissimilar, pectinate in a single row of five teeth increasing in length distally. Third claw strongly curved, long and thin, with a single tooth near base. The base of the third claw rests on a peculiar, bilobed corrugated pad or pulvillus. A pair of powerful spurious claws is present as well as three pairs of finely serrated bristles.

The shape of the abdomen is shown in figures 1 and 3. It has two pairs of dorsal humps of which the posterior pair is by far the largest. Anteriorly the abdomen overhangs the carapace. The single tracheal spiracle is situated a little in front of the colulus. The latter is well developed. The anal tubercle is large, coneshaped, almost as long as the spinnerets. Spinnerets six. Anterior pair heaviest, coneshaped, contiguous, with hemispherical terminal joint. Median

pair very short and slender. Posterior pair cylindrical, as long as anterior pair, but more slender.

Palp. The trochanter of the palp is inserted on the dorso-lateral angle of the maxilla, close to the base. The cymbium is large and has a basal apophysis in the shape of a wide scoop with a terminal and two lateral lobes which are bent upward. There are six spines present on the dorsal surface of the cymbium (none on other joints). Peculiar, very short hairs are present on the apophysis, each hair sitting on a low pedestal. There are several trichobothria on the tibia, one of them of extraordinary length and stoutness. One trichobothrium is situated near the apical end of the cymbium. The embolus has the shape of a short, rather stout, dark colored cylinder. The integuments are clothed with simple hair.

Color in alcohol: Generally white except for dark pigment around the eyes and the dusky submarginal bands on the sides of the carapace. An irregular, red mark on the sternum. Abdomen white and buff, white predominating and broken up into small patches, the color due to guanine cells underlying the hypodermis. On each side of the abdomen back of the lung area are 5 or 6 narrow, more or less parallel black lines. Ventral postgenital area dark with a white mark at each side. A dusky, irregular band around anterior spinnerets. The spinnerets buff.

Two males of this species were captured by me on August 2d and 3d, 1938, on Barro Colorado Island, C. Z., situated in the Gatun Lake. They were found on low vegetation on the Snyder Molino Trail about 400 meters from the laboratory. One of these males is the type, described above. The other, the paratype, is somewhat smaller, 2.93 mm. long, but in every respect identical with the type.

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ZYGMUNT MOKRZECKI: A PROMINENT POLISH ENTOMOLOGIST by JANUSZ ANTONI CZYZEWSKI. Extract from the Entomological Bulletin of Poland. T. 14–15, 1935–6. (1937).

This publication issued by the Polish Entomological Society has only recently come to hand but even at this late date it deserves mention as there is much in it to interest entomologists the world over.

The article as a whole is in Polish and so to those of us unfamiliar with this language, difficult to appreciate but there is an extended summary in English which includes a short biographical sketch, a discussion of his main contributions to entomological science, his influence in general science in Poland and a tribute to his personality and character. Two quotations will illustrate this feature:

> "Professor Mokrzecki represented a type of scientist entirely different from that of an average scientist of today. One is immediately struck by his attitude to life in general, and to science in particular, free from that inhumanity which so often characterizes scientists. A great love of beauty in all its forms, fantasy, imagination, romanticism and an all pervading individualism—these are the outstanding characteristics of Mokrzecki which have colored his whole activity."
>
> "To the last moments of his life he made the impression of a man mentally young, who understood youth and the new tendencies in science and all fields of national and human life in general."

Of interest in America are the papers (1926) entitled, "Attempts of controlling forest pests by means of gas and poisonous powders" and "Controlling pests by means of airplanes and gas candles," this especially for Gipsy Moth. There is also mention of assistance to two American entomologists S. S. Crossman and R. T. Webber for a parasite station at Damienice, and in 1927 with C. F. W. Muesebeck and C. R. Brown a movable station for the culture of parasites in a forest near Warsaw.

An appreciated feature is the inclusion of a number of photographs showing him at different periods in his life, and groups of entomological or scientific associates. One of these taken in 1927 was taken on the occasion of our own great entomologist Dr. L. O. Howard's visit to Skierniewice and shows our former chief entomologist seated between Dr. Mokrzecki and his daughter. Another shows Dr. Mokrzecki with Dr. Muesebeck and Mr. Brown.

A reading of this interesting paper will well repay any entomologist.

—HERBERT OSBORN.

ANTS OF THE GENUS MACROMISCHA ROGER IN THE UNITED STATES

(Hymenoptera: Formicidae)

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This rather large and extremely interesting genus of ants is known from approximately 80 forms. Only three of these occur in the United States, one of which, *Macromischa polita*, is new and is described herein. Roger undoubtedly appreciated the complexity of the genus when he so appropriately named it. Although the ants represent some of the most beautiful and striking species known, the wide range in the diversity of their structure and habits has made them extremely difficult to classify clearly. Three subgenera have been erected for the purpose of clarifying the situation, and on the basis of the worker and queen they have been distinguished as follows: Head quadrate, petiolar peduncle short and stout, *Antillaemyrmex* Mann; head not quadrate or the petiolar peduncle more slender, thorax elongate, epinotum unarmed, *Croesomyrmex* Mann; head not quadrate or the petiolar peduncle more slender, thorax shorter or the epinotum spinose, *Macromischa* s. str.

According to Wheeler (Bull. Mus. Comp. Zool. 72: 4, 1931) these subgenera are distributed as follows: *Antillaemyrmex* to the West Indies and Florida; *Croesomyrmex* to Cuba; and *Macromischa* s. str. to the Bahamas, Greater Antilles, and North America from Texas to Panama. In 1931 Wheeler, in the same publication mentioned above, went so far as to raise *Antillaemyrmex* and *Croesomyrmex* to generic rank, but at the same time he admitted the weakness of this stand on the basis of biological and morphological evidence presented by a small number of species. Later (Bull. Mus. Comp. Zool. 81: 441, 1937) he returned these groups to subgeneric ranking with the statement "the recent discovery by Dr. Aguayo of a subspecies of *C. wheeleri* Mann with vestigial epinotal spines, and the discovery by Dr. M. R. Smith of a subspecies of *M. isabellae* Wheeler without epinotal spines, necessitates a return to Mann's original conception." I would go even further than this, as I believe

there is sufficient evidence at hand now to show that the forms considered as *Macromischa* in the broad sense cannot be clearly segregated into subgenera and therefore the subgeneric names should be dropped. I believe the accumulation of additional material in this group will only strengthen this contention.

Of the species treated below, *Macromischa subditiva* was formerly assigned to *Macromischa* s. str. and *floridana* to the subgenus *Antillaemyrmex*. In this paper known castes of each species are described, and a key is given for the separation of the workers of the various species.

KEY TO THE SPECIES OF MACROMISCHA OF THE UNITED STATES

(Workers only)

1. Antennal scape robust, short, not reaching quite half-way between the eye and the posterior border of the head; sculpturing of head, thorax, petiole and postpetiole rugose reticulate; eye with unusually large facets; Florida (Pl. I, *C*).....**floridana**
   Antennal scape slender, and extending farther posteriorly; sculpturing not as above; eye with smaller facets..... 2
2. Peduncle of petiole at least twice length of petiolar node; petiolar node short; general color light to deep brown; pilosity of scape closely appressed; Texas. (Pl. I, *A*).....**subditiva**
   Peduncle of petiole length of node or less; petiolar node long; general color blackish; pilosity of scape suberect; Arizona. (Pl. I, *B*).....**polita**

Macromischa subditiva Wheeler

Macromischa subditiva Wheeler, Psyche 10: 99, fig. 5, 1903 (worker).
Macromischa (*Macromischa*) *subditiva* Mann, Bull. Amer. Mus. Nat. Hist. 42: 408, 1920.
Macromischa (*Macromischa*) *subditiva* Wheeler, Bull. Mus. Comp. Zool. 81: 15, 1931 (female).

Worker (Pl. I, *A*).—Length 2–2.5 mm.

Head, exclusive of mandibles, longer than broad, with convex posterior border, rounded occipital angles, and moderately convex sides. Eye convex, at least length of its greatest diameter from base of mandible. Antenna 12-segmented; scape moderately slender, extending farther posteriorly on head than scape of *floridana*; first funicular segment exceeding combined length of two succeeding segments, second to seventh funicular segments about as broad as long, last funicular segment exceeding combined length of two preceding segments. Clypeus convex, anterior border broadly rounded, posterior border extending well back between frontal carinae. Frontal area triangular, not clearly defined. Mandible with 5 or 6 teeth, the three apical teeth fairly large and prominent. Thorax rather short and robust, dorsum in profile convex, evenly arched; pronotum with rounded humeral angles; promesonotal and mesoepinotal sutures faintly indicated or absent. Epinotal spines prominent, placed close to each other basally but diverging backward, outward, and upward. Petiole with a peduncle at least twice length of node; in profile, the node is much shortened, rounded and narrow at the summit, and with almost perpendicular anterior and

posterior faces; viewed from behind, the summit of the node is horizontal, blunt, and almost straight. Anterior ventral surface of peduncle with a small but distinct tooth. Postpetiole transversely elliptical, not much wider than petiole but approximately twice as wide as long. Gaster with distinct basal angles. Femora incrassate, hind pair more noticeably so.

Posterior surface of head, dorsum of thorax, petiole, postpetiole, and gaster smooth and shining; remainder of body subopaque. Mandibles longitudinally striate, clypeus longitudinally rugulose, with a distinct median carina, which often extends onto the frontal area; remainder of head finely rugulose reticulate, the rugulae especially conspicuous on front of head and on cheeks. Pleura of mesothorax and metathorax reticulate punctate. Legs finely reticulate.

Head, thorax, and gaster bearing sparse, erect, obtuse, grayish hair; appendages with small, appressed pubescence.

Color varying from light to deep brown; with lighter epinotal spines, coxae, trochanters, bases of femora, tibiae, and tarsi.

Queen.—Length 3.5 mm.

Very similar to worker except in size and the usual morphological differences. Also differing as follows: Epinotal spines proportionally shorter and more robust, with less acuminate tips, interbasal space exceeding length of spines. Sculpturing of body more pronounced; upper surface of head with coarse, longitudinal rugulae, and finely punctate interrugal spaces; scutum, paraptera, and scutellum of mesothorax bearing fine, longitudinal striae, with very fine punctations between striae. Body duller and apparently slightly darker in color than that of worker.

Male.—Length 2.2 mm.

Head, exclusive of mandibles, approximately as broad as long, with strongly convex posterior border, and moderately convex sides. Eye extremely large, convex, occupying at least half length of side of head, its anterior border almost touching base of mandible. Clypeus convex. Mandible small, toothed. Postocellar line longer than lateral ocellar line. Antenna slender, 13-segmented, the last 3 segments considerable enlarged. Thorax without Mayrian furrows, but with faint parapsidal furrows. Scutellum strongly gibbous. Epinotum without spines or tubercles. Wings pale, translucent, with very faint veins; discoidal, cubital, and radial cells lacking, but stigma well developed. Legs rather long and slender, femora not incrassate. In profile, peduncle of petiole noticeably short, its dorsal surface forming a gradually ascending slope, which meets the somewhat flattened posterior surface of the node to form a bluntly angular, but low node. Postpetiole from above transversely elliptical, wider than long, but not much wider than petiole. Gaster with basal angles.

LEGEND FOR PLATE I

A, Worker of *Macromischa subditiva* Wheeler; *B*, Worker of *Macromischa polita*, new species; *C*, Worker of *Macromischa floridana* (Wheeler). Drawn by H. B. Bradford. No attempt has been made to show the finer details of sculpturing in *A* and *B*.

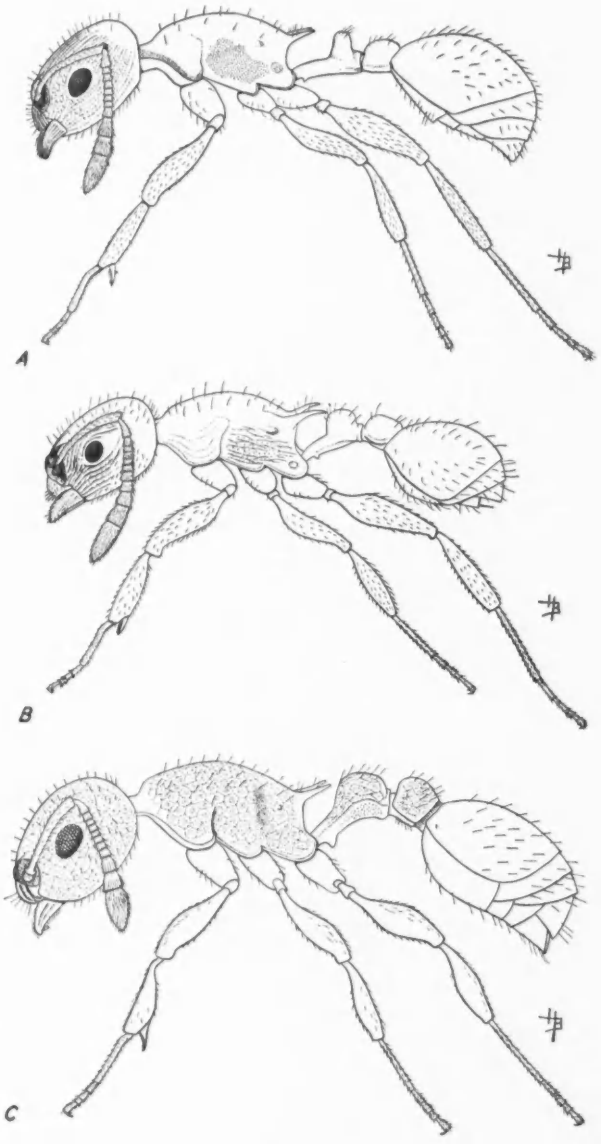

PLATE I

Hairs grayish, short, erect, sparse; more abundant on gaster, especially toward apex. Pilosity sparse, appressed; most easily discernible on appendages.

Brown; appendages lighter; apices of coxae, trochanters, bases of femora, and tarsi even lighter.

Cotype localities.—Walnut Creek, near Austin, and New Braunfels, Tex. (W. M. Wheeler.)

Other localities.—Del Valle, Tex. (W. M. Wheeler); Victoria, Tex. (J. D. Mitchell); Harlingen, Tex. (R. A. Vickery).

The above descriptions are based on 2 dealated queens, 1 male, and numerous workers collected by J. D. Mitchell in Victoria, Tex. All these are in the United States National Museum with the exception of 1 queen and 14 workers (same locality and collector) lent me by the Museum of Comparative Zoology (Harvard University). The male is described in this article for the first time.

The worker of *Macromischa subditiva* can be readily distinguished by the peculiarly shaped petiole, the peduncle of which is at least twice the length of the petiolar node; the rather uniform brownish color of most of the body; the obsolescent or missing thoracic sutures; the slender antennal scapes; and the sculpturing of the body.

Wheeler records this species as nesting in the bark of willow trees. The colonies are thought to be small and the habits of the ants in general similar to those of certain species of *Leptothorax* Mayr.

Macromischa polita, new species

Worker (Pl. I, *B*). Length 2–2.4 mm.

Head, exclusive of mandibles, subrectangular, slightly longer than broad; posterior border faintly convex; occipital angles strongly rounded, and sides moderately convex. Eye convex, removed by at least the length of its greatest diameter from base of mandible. Antenna 12-segmented; scape slender, extending farther posteriorly on head than scape of *floridana*; first funicular segment approximately length of the three succeeding segments combined, club 3-segmented, as long as remainder of funiculus. Clypeus convex, more strongly projecting than that of *subditiva*, posterior border rounded and extending well back between frontal carinae. Frontal area small, triangular, poorly defined. Mandible 5-toothed, the two apical teeth clearly visible. Thorax short, robust, in profile with strongly convex and rather evenly arched dorsum; from above somewhat broader anteriorly than posteriorly, with rounded humeral angles and no promesonotal or mesoepinotal sutures; epinotal spines large, at least twice length of their interbasal space. Femora and tibiae incrassate, especially those of the posterior pair of legs. In profile, petiolar peduncle short, approximately length of bulbous node,

which has subvertical anterior and posterior surfaces, and an evenly convex dorsal surface; peduncle with a small ventral tooth; from above, petiolar node somewhat campanulate; postpetiole transversely elliptical, approximately one and one-half times as broad as petiolar node. Base of gaster with strong angles.

Head, thorax, petiole, postpetiole, gaster, femora, and tibiae smooth and shining; mandibles longitudinally striate, clypeus with a prominent median carina and several lateral rugulae, cheeks and anterior portion of each frontal carina with longitudinal rugulae, meso- and metapleura of thorax longitudinally rugulose punctate.

Hairs grayish, slender, erect, moderately abundant on all parts of body; shorter and more suberect on appendages.

Black; with lighter mandibles, epinotal spines, coxae, trochanters, bases of femora, tibiae, and tarsi.

Cotype localities.—Arizona: Catalina Mountains (2 workers); along Santa Cruz River, 4 miles from Tucson (4 workers); Phoenix (5 workers); Florence (2 workers); 30 miles east of Sells (1 worker); Sabino Canyon (7 workers); 8 miles northeast of Tucson (3 workers); 5 miles north of Tucson (1 worker); by the Riollito, a little north of Tucson (1 worker).

Cotypes.—No. 53249, United States National Museum.

Described from 26 specimens, collected by Robert G. Wesson. All these are in the United States National Museum collection except the following: 2 workers from Phoenix, Robert G. Wesson; 2 workers from along Santa Cruz River, American Museum of Natural History; 2 workers from along Santa Cruz River, Museum of Comparative Zoology (Harvard University).

The worker of this species is characterized by its strongly convex, evenly arched thorax; absence of dorsal thoracic sutures; peculiarly shaped petiole, the peduncle of which is approximately the length of the petiolar node; the smooth and shining surface of the body; and the general black color.

According to Mr. Wesson, the workers of this ant seem to be most commonly found on the ground in the vicinity of irrigation canals, washes, and rivers. Specimens have been taken at altitudes up to 4,500 feet. They are rather shy and sensitive to heat. Little else is known of their biology except that one nest was found in the bark of a cottonwood tree, about 2 inches above the surface of the soil.

Macromischa floridana (Wheeler)

Antillaemyrmex floridanus Wheeler, Bull. Mus. Comp. Zool. 72: 27–28, 1931 (worker).

Macromischa (*Antillaemyrmex*) *floridana* Wheeler, Bull. Mus. Comp. Zool. 81: 465 (1937).

Worker (Pl. I, *C*).—Length 2.3–2.6 mm.

Head, exclusive of mandibles, subrectangular, scarcely longer than broad, posterior border nearly straight, posterior angles rounded, and sides feebly convex. Eye rather large, strongly convex, with large facets; the length of its greatest diameter from base of mandible. Antenna 12-segmented; scape curved, stout, short, reaching to less than half distance between eye and posterior border of head; first funicular segment as long as funicular segments 2–5, funicular club prominent, 3-segmented, slightly exceeding length of remainder of funiculus. Clypeus convex, its anterior border rounded, its posterior border broadly rounded and extending backward between frontal carinae. Frontal area not well defined. Mandible small, 5-toothed, all teeth clearly visible. Thorax in profile short, stout, convex, with rather evenly arched dorsum; from above, broader anteriorly than posteriorly, and with distinct humeral angles, without promesonotal and mesoepinotal sutures; epinotal spines scarcely longer than their interbasal space, and diverging, extending backward, outward, and upward. Legs rather short, femora and tibiae incrassate. Petiolar peduncle stout, approximately one-half length of node, antero-ventral surface with a prominent tooth; in profile, petiolar node large, somewhat subcuboidal, its anterior slope forming an obtuse angle with the pedicel, its dorsal surface subconvex, and its posterior slope abrupt, nearly perpendicular; viewed from above, node slightly wider than long, and rounded anteriorly and laterally; postpetiole transversely elliptical, one and a half times as broad as long. Gaster large, and with slight basal angles.

Legs and gaster somewhat shining; remainder of body subopaque. Mandibles striato-punctate; clypeus longitudinally rugose laterally, and with a prominent median carina; head, thorax, petiole, and postpetiole rugose reticulate.

Hairs pale, erect, blunt, but not coarse, fairly abundant and well distributed over body; antennal scapes and tibiae with more delicate, suberect hairs.

Pale ferruginous to light yellowish brown; appendages paler, with apices of femora and of tibiae, and the tarsi, brownish; mandibular teeth and eyes black.

Cotype locality.—Paradise (Dade County), Fla. (W. M. Wheeler).

The description of the worker is based on 3 cotype specimens in the collection of the United States National Museum. These specimens were collected by Wheeler from cavities in the branch of a small tree. He states that "the behavior of this ant was so much like that of certain species of *Leptothorax* that I at first assigned it to that genus."

The worker of *floridana* is characterized by its very short and robust antennal scape; rather large, convex, and coarsely facetted eye; rugose reticulate sculpturing; and pale-colored body. The sculpturing of the body and the shape of the petiole

and postpetiole are somewhat suggestive of that of the worker of *Tetramorium guineense* (F.).

The three specimens of *floridana* agree so closely with cotypes of *Macromischa allardycei* Mann. of the Bahama Islands, that I at first considered synonymizing *floridana* with that species. After studying specimens of both species, however, it appears to me that the worker of *floridana* is much more robust; has a proportionally broader head, with less convex posterior border; more robust epinotal spines; and the petiolar node arising more abruptly from the pedicel. The workers of *allardycei* appear to show a greater tendency to polymorphism than do the workers of *floridana*. The cotypes of *allardycei* were collected from the hollow stem of *Cladium jamaicensis* on the border of a swamp near Grants Town and the Blue Hills (Bull. Amer. Mus. Nat. Hist. 42: 414–415, 1920).

STATISTICAL METHODS APPLIED TO EXPERIMENTS IN AGRICULTURE AND BIOLOGY, by G. W. SNEDECOR. Revised, pp. i-xiii and 1–388, 22 text figures, 143 tables, 417 examples. 1938. COLLEGIATE PRESS, INC., Ames, Iowa. Price $3.75.

The first edition of Snedecor's "Statistical Methods", which appeared in 1937, was reviewed in the ANNALS 31: 4. 1938. As the present edition is not changed in character, we refer the reader to the previous notice for the praise that it deserves as a guide and aid to the design and analysis of experiments in economic entomology and other fields of applied biology. In the book the present edition is called "revised," but the publisher in his letter concerning it refers to it as the second edition. The latter term seems more appropriate because the present edition is larger than the first by 47 pages, including additional tables and examples. Perhaps because it followed the heels of the first edition so closely, the author did not write a new preface. The following quotation from the publisher's letter describes the new material:

> "Rates, ratios, and percentages have been discussed in six passages inserted at appropriate places. The presentation of analysis of variance in Chapter 10 has been revised, as has the treatment of randomized blocks and the Latin square in Chapter 11. Other added sections deal with experiments on annual crops at several places and in several seasons. Experiments with perennial crops serve to introduce the subject of three criteria of classification. In multiple regression, the calculations for four and more variables have been introduced. The topics of missing plots as well as proportionate and disproportionate subclass numbers have been included."

To the economic entomologist enumeration data in the form of per cent mortality, per cent infested, etc., are among the most important to be analyzed. It is hoped that subsequent editions will go into this subject more fully. Reference is made to the useful papers of Bliss, but a table of probits is not given.—F. L. C.

THE BIOLOGY AND TAXONOMY OF THE NEARCTIC SPECIES OF OSMODERMA

(Coleoptera, Scarabaeidae)

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The genus *Osmoderma*, as represented in North America, was heretofore recognized by some entomologists to be composed of several species and subspecies, whereas this study limits it to only two species. Members of this genus occur in the southern part of most of the Canadian provinces adjoining the United States and throughout the United States east of the Rocky Mountains except for the southernmost States. The large, clumsy adults, which are nocturnal and good fliers, are often taken at electric lights, in bait traps, or afield in or near wooded areas on dull days. Harris (7,[1] p. 42) writes that the adults "conceal themselves during the day in the crevices and hollows of trees, where they feed upon the sap that flows from the bark." When captured the beetles emit a very strong but not unpleasant odor which many writers have compared to Russian leather. This odor suggested to French naturalists the name *Osmoderma*, that is, scented skin.

The larvae of both species live in the decaying wood of fruit and forest trees, where they consume the wood and induce more rapid decay. They are usually found in the decadent trunks or branches of large trees, or sometimes in old felled trees and stumps. W. L. Devereaux, in correspondence with Packard (12, p. 283), stated that the larvae of both species

[1]Numbers in parentheses refer to Literature Cited, p. 524.

channel up the heart of large trees and often enter into close proximity with the live wood. Quoting Mr. Devereaux, after Packard (12, p. 283–284), "None of our large trees, as a rule, are exempt from their burrows, having them either at the lower part or else at the large fork or top. I have seen enormous trees in full leaf and blossom, in a still day, suddenly break off midway a trunk, fall to the earth with a crash, startling and mysterious enough to any hearer in such a day of reigning quiet. Where the fracture most often occurs no decay of the heart is present, but is completely filled with the burrows of the *Osmoderma*." Most writers are agreed, however, that the injury inflicted on living tree tissue, if any, is of little consequence.

Much of the early taxonomic work on the North American species of this genus, which was carried on in Europe, was badly confused because of the inability of workers to separate the sexes, erroneous locality labels, and the use of color as a means of segregating species. In 1871 Horn (8) of the United States redescribed the European species *eremita* Scop. as *Osmoderma socialis*, n. sp., from some specimens apparently erroneously labeled or accidentally imported, no locality data being included with the description. A later worker, Beaulieu (1), recognized that our two species were variable in form and color and suggested that one should not be deceived by this variability and describe additional species. Discussing the genus *Osmoderma*, Casey (3, p. 372) made this statement: "As in all the other genera of this tribe, the delimitation of species and subspecies among the numerous individuals in most collections is not altogether satisfying, but insofar as can be determined at present, the forms worthy of names before me are as follows, all of the characters being recorded from the male, except when the contrary is stated." On page 377 he writes that "Besides considerable variability within specific or subspecific limits, some parts of the body seem to be peculiarly subject to accidental deformation in this genus." However, in spite of the recognized variability within the species and lower categories of this genus, Casey saw fit to describe a number of forms as new, even establishing two subspecies and applying one species manuscript name on the basis of a single example in each case.

Except for Wickham's description of *Osmoderma montana* in 1920 (17), which was based chiefly on the characters of the internal genitalia, all previous studies on the classification of this genus have been on a morphological basis, and limited to

the external features of the adult. Believing that a thorough taxonomic study should be based on a quantitative sample, I assembled approximately 1,150 specimens from different individuals and institutions, acknowledged elsewhere in this paper, of the United States and Canada. As with the genus *Trichiotinus* of the same tribe, a study of the male and female genitalia revealed excellent characters for specific differentiation. Our two American species differ so markedly in the structure of the pronotum and the internal genitalia as to suggest subgeneric rank. Dissections of the male genitalia of a number of specimens of *O. eremita*, a European species which externally resembles our *scabra*, disclosed a grotesque structure very unlike the genitalia of our native species. The biological studies carried on with the American species, although not so extensive as desired, have aided in evaluating variations in form, color, punctation, and genitalia.

THE BIOLOGY OF OSMODERMA SCABRA (BEAUVOIS)

Past Studies.—This insect, because of its sculpture, is commonly known as the rough *Osmoderma*. It is also called the rough flower beetle, although, so far as I know, the adults are seldom taken on flowers. Harris (7) observed adults of this species in the hollows of cherry and apple trees and states that the beetles are fond of the juices of these trees. Besides feeding on the sap of injured trees, these nocturnal insects have been seen by Lugger (11) to feed on a ripe apple. He also says that the adults hide during the day near the bases of trees, while Glover (5) writes that adults appear in summer and are found on the foliage of apple, oak, and other fruit and forest trees.

Osmoderma scabra is recorded as having been reared from larvae feeding on the decaying wood of the following trees: apple and cherry—Harris (7); beech—Schaupp (13); sweet gum, hickory, poplar, willow, sycamore, sassafras, maple, oak, and chestnut—Beutenmüller (2); and birch—Dunn (4).

According to Harris (7, pp. 42–43), the larva in autumn "makes an oval cell or pod, of fragments of wood, strongly cemented with a kind of glue; it goes through its transformation within this cell, and comes forth in the beetle form in the month of July." On July 15, 1879, Schaupp (14) isolated ten larvae of this species in a tin box with the same mould and black earth in which they were found within a beech-tree cavity. The five larvae surviving until late in October made, according to Schaupp (14, p. 98), "oblong cocoons of earth, outside rough, inside very fine and smooth, 30 mm. long and 24 mm. broad, considerably firm." Three of the larvae pupated during May, one adult emerging on the 9th.

The Present Study.—On October 2, 1932, three practically mature grubs of *Osmoderma scabra*, one of which had already formed a cocoon, were removed from the moist and decayed portion of a maple trunk at

Anoka, Minn. These larvae, as with subsequent collections from Minnesota, were isolated in 3-ounce or 4-ounce salve boxes supplied with small particles of decayed wood and kept in a basement room at about 74° F. One of the above larvae succumbed late in November; the other two completed their transformations and emerged as adults the first week of the following January.

On October 16, 1932, A. C. Hodson collected for me a cocoon containing a larva from an old maple stump at Taylors Falls, Minn. This particular specimen pupated on December 16 and emerged on the last day of the month. At the same locality on May 6, 1933, I took 3 prepupae in cocoons and 7 larvae about 22 mm. in length from a broken-over and decayed black birch trunk. The former transformed to adults late in May. Although the larvae seemingly fed well in captivity, none were reared to maturity. Five died after 6 to 8 months' isolation, and 2 after 13 months. One of the latter grubs was practically mature, since it had attained a length of 37 mm. Considering the size of this larva when collected and its development in captivity, and allowing for overwintering periods, it seems probable that this species has a 3-year life cycle.

The prepupae of *Osmoderma scabra* are about 28 mm. long and 11 mm. wide. This stage, which required 7 days for 2 Minnesota specimens, is passed within an oblong or egg-shaped cocoon made up of bits of decaying wood tightly cemented together. These range from 29 to 33 mm. in length and from 18 to 20 mm. in width, and may be either rough or smooth externally, internally very smooth. The cocoons are of the same color as the debris in which they are found and hence are often broken prior to detection. Measurements based on 5 pupae averaged 26.6 mm. for length and 11.7 mm. for greatest width. The mean length of this stage for 5 individuals was 16 days (minimum 15, maximum 18 days). Emerging adults were isolated with moist decayed wood, where the males lived for 3, 11, and 16 days, respectively, and the females for 28 and 32 days.

On December 27, 1935, T. H. Jones collected for me 10 large larvae, most of which were in cocoons, of this species from a decayed apple stump at Easton, Mass. The larvae were subsequently isolated individually in salve boxes and kept in a basement rearing room which ranged in temperature from 68° F. to 80° F. In March, just prior to prepupation, one of the larvae measured 43 mm. in length and 13 mm. at its greatest width. The prepupae were approximately the same size as the Minnesota specimens, and, in the four observed cases, the duration of this stage was 6 or 7 days for each specimen. Eight of the larvae completed their growth, and, with one exception, pupated and emerged the following March. The longevity of four male beetles was 29, 36, 38, and 46 days, respectively.

Based on 348 labeled specimens collected throughout the geographical range of the species and examined in the systematic portion of this paper, 94 per cent of the adults were captured during the months of June, July, and August. Approximately 56 per cent of the total number of beetles were taken during the month of July.

Past Studies.—Because of its sculpture, this scarabaeid is sometimes called the smooth *Osmoderma;* also, the hermit flower beetle since the species, as signified by its name, is an inhabitant of the wilderness. However, as with the other species, specimens are seldom taken on flowers, so the latter name is not entirely appropriate. Glover (5) writes that the beetle feeds upon the sap of apple and cherry trees. Harrington (6) obtained adults from pupae (in oval cocoons made of wood particles) found in a small hollow where decay had been initiated after the breaking off of a hickory limb. Lugger (11) states that the beetles not only feed on the sap of injured trees but also have been observed to feed on a ripe apple. He also mentions that adults appear during the months of July or August, or early in September.

During July of 1874 at Saint Louis, Mo., Packard (12, p. 283) observed an abundance of *eremicola* eggs apparently at the base of the hollow trunk of a large elm tree, the decayed part of which had been reduced "to a tan bark red, excrementitious powder, of which there were bushels filling the base of the cavity." He describes the eggs as being "perfectly spherical, about 3 mm. in diameter, opaque-white, and with tolerably tough skin." Sweetman and Hatch (16) fed flowers to adults, chiefly dandelion and *Spiraea* and obtained deposition on decayed wood kept in cages. On page 264 they make the following remarks about the egg stage: "The eggs are more or less spherical, opaque, and white. Their diameter at the time of oviposition was about one-eighth inch and about twice this at the time of hatching. They were laid in the wetter portions of the wood and hatched in from 7 to 16 days, averaging 12 days." Based upon 5 females, Sweetman and Hatch (16) determined the average preoviposition period to be 26 days (minimum 21, maximum 33), the average oviposition period 24.6 days (minimum 5, maximum 53), the average number of eggs 38.8 (minimum 19, maximum 64), the average life of the female 58 days (minimum 31, maximum 74), and the average life of the male to be 38.4 days (minimum 25, maximum 48).

The larvae of *Osmoderma eremicola* have been recorded as occurring in the decaying wood of the following trees: Beech—Schaupp (13); hickory—Harrington (6); elm—Packard (12); apple and cherry—Lugger (11); oaks and maples—Beaulieu (1); and cottonwood—Sweetman and Hatch (16).

On April 16, 1924, Sweetman (16) took 14 *eremicola* larvae in their pupal cells in a cottonwood tree at Ames, Iowa. He examined the larval borings and determined that they were at least one-half inch from the living tissue of the wood. The larvae were transferred to the laboratory to undergo metamorphosis and three individuals spent about 16 days in the pupal stage. Sweetman and Hatch (16, pp. 264–265) state that "No grubs were reared to maturity but one was nearly full grown when lost after feeding continuously for about 18 months. Allowing for periods of hibernation outdoors, this indicates a 3-year cycle for the species."

The Present Study.—During September 1933 a number of oak trees which had died apparently because of a combination of factors—*Agrilus bilineatus* (Web.) attack, drought, and the shoestring fungus—were removed on the University Farm Campus, Saint Paul, Minn. The decayed interior portion of one large branch of one tree and the trunk of another contained an abundance of larvae living together socially. Small, medium, and large grubs were represented in both trees. Of the 9 large grubs isolated under the same laboratory conditions as the Minnesota specimens of *scabra* 5 pupated within the next 4 or 5 months whereas 4 required from 13 to 15 months.

The prepupae of *Osmoderma eremicola* are approximately 31 mm. long and 12 mm. wide. As with *O. scabra* the prepupal and pupal stages are passed within tough oblong cocoons composed of decaying wood particles tightly cemented together. Under laboratory conditions the mean length of the prepupal stage for 9 individuals was 8.1days, range 6 to 12 days. The average length of 5 pupae for this species was 26.7 mm.; the average greatest width, 12.8 mm. Four individuals were observed to require 16, 17, 19, and 21 days, respectively, to complete this stage.

As mentioned previously, three sizes of grubs were collected in the field at Minnesota during the same month. Allowing for over-wintering periods and remembering that some of the larger grubs required from 13 to 15 months to complete their development in the laboratory, I am inclined to believe that *eremicola* needs at least 3 years to complete its life cycle under field conditions in Minnesota.

It is interesting to note that of 310 labeled specimens collected throughout the distributional range of the species and examined in the systematic portion of this paper, 93 per cent were collected during June, July, and August. About 45 per cent of the total number of beetles considered above were captured during July.

TAXONOMY OF THE GENUS OSMODERMA

More than 1,150 specimens have been examined individually during this investigation, and finally determination labels were affixed to all specimens. The internal genitalia of about 165 individuals were either everted (females), partially withdrawn (males), or extracted and placed on paper points directly beneath the specimens from which they were withdrawn for study. Drawings of the ventral aspect of the female genitalia showing the shape of the apical sclerites have been included for each species, since they offer distinguishing characters if not distorted upon dissection. The configuration of the parameres in the male genitalia afford excellent characters for separating the two species and therefore have been figured. In the pages to follow I have included a key to the species based on external characters, a bibliographic history of each species, a redescription of both sexes of each species, location and notes on type specimens, comparative notes, and a detailed treatment of the geographic distribution of each species.

HISTORICAL ACCOUNT AND DIAGNOSIS OF GENUS OSMODERMA

The Genus **Osmoderma** Lep. and Serv.

Osmoderma Le Peletier and Serville, Encycl. Méth. 10: 702, 1825.
Gymnodi Kirby, Zool. Jour. 3: 157, 1827.
Gymnodus Kirby, Fauna Bor. Amer. 4: 139, 1837.

According to the literature citations given by Schönherr (15), early writers assigned members of this genus to the following genera: *Scarabaeus*, *Trichius*, *Cetonia*, and *Melolontha*.

The first North American species discovered, *eremicola* was described by Knoch (1801) under the genus *Cetonia*, while the second species of this continent, *scabra*, was described by Beauvois (1805) under the genus *Trichius*.

In 1825 Le Peletier and Serville subdivided the genus *Trichius* and in so doing erected the genus *Osmoderma*, under which they placed *T. eremita* of Europe and *T. scabra* of America. Kirby, in 1827, divided the genus *Trichius* into subgenera and proposed the subgenus *Gymnodi* to include *T. eremita* and others undescribed from North America. Subsequently Kirby (1837) described two supposedly new species under the subgenus *Gymnodus*. Except for papers by Kirby, all literature referring to the North American species since 1825 has been written under the generic name *Osmoderma*.

According to a free translation of their words, Le Peletier and Serville (1825, p. 702) characterized the genus *Osmoderma* as follows: "Mandibles entirely corneous. Scutellum a rectilinear triangle, longer than wide, longitudinal furow in its middle. All the tarsi shorter than the tibiae. Anterior tibiae tridentate on external side. Mentum naked. Last joint of palp slightly dilated externally." Members of this genus in North America are large (14.5 mm. to 28 mm. long, exclusive of head), broad (greatest width 8 mm. to 15.5 mm.), practically naked, unspotted; thorax distinctly narrower then elytra and rounded on the sides; the hind coxae are contiguous and the mesepimera conspicuous from a dorsal viewpoint.

KEY TO THE SPECIES

Pronotum with four distinct subanterior ridges; elytra with moderate to coarse sculpture..... **scabra**
Pronotum with a deep transverse concavity, with its anterior margin cariniform; elytra smooth except for rugulose margins..... **eremicola**

SYSTEMATIC TREATISE OF THE SPINES

1. **Osmoderma scabra** (Beauvois)

Trichie scabre Beauvois, Ins. Afr. et Amer., pp. 58–59, fig. 2, 1805.
Osmoderma scaber Gory and Percheron, Mon. Cet., pp. 47, 76; pl. 8, fig. 2, 1833.
Trichius (Gymnodus) foveatus Kirby, Fauna Bor. Amer. 4: 140, 1837.
Trichius (Gymnodus) rugosus Kirby, Fauna Bor. Amer. 4: 140, 1837.
Osmoderma scabrum Burmeister and Schaum, *in* Germar, Zeitschr. Ent. 2: 384, 1840; Bainbridge, Ann. and Mag. Nat. Hist. 6: 481, 1841; Bainbridge, Trans. Ent. Soc. Lond. 3: 215, 1842; Bedel, L'Abeille 30: 254, 258, 1906.

Osmodermum rugosum Burmeister and Schaum, *in* Germar, Zeitschr. Ent. 3: 229–230, 1841.
Osmodermum scabrum Burmeister and Schaum, *in* Germar, Zeitschr. Ent. 3: 229–230, 1841.
Osmoderma Beauvoisii Bainbridge, Ann. and Mag. Nat. Hist. 6: 481, 1841; Burmeister, Hand. Ent. 3: 717, 1842; Bainbridge, Trans. Ent. Soc. Lond. 3: 215, 1842.
Osmoderma rugosa Burmeister, Hand. Ent. 3: 716, 1842; Schaum, Ann. Soc. Ent. France, second series, 2: 397, 1844.
Osmoderma scabra Castelnau, Hist. Nat. Col. 2: 159, 1840; Burmeister, Hand. Ent. 3: 715–716, 1842; Schaum, Ann. Soc. Ent. France, second series, 7: 289, 1849; Horn, Canad. Ent. 8: 168, 1876; Fletcher, Ann. Rept. Ent. Soc. Ontario for 1879, p. 71, 1880; Saunders, Insects Injurious to Fruits, p. 26, fig. 12, 1883; Benderitter, Miscl. Ent. 4(8): 97–98, 1896; Harrington, 27th Ann. Rept. Ent. Soc. Ontario, 1896, p. 72, fig. 76, 1897; Patch, Maine Agr. Expt. Sta. Bull. 162: 361, figs. 55–57, 1908; Blatchley, Col. of Indiana, p. 1002, fig. 420, 1910; Casey, Mem. Col. 6: 373, 1915; Zeliff, Proc. U. S. Nat. Mus. 82 (Art. 23): 1–3, 1933.
Osmoderma delicatula Casey, Mem. Col. 6: 372–373, 1915. (New synonymy.)
Osmoderma scabra rugosa Casey, Mem. Col. 6: 373–374, 1915.
Osmoderma scabra gracilipes Casey, Mem. Col. 6: 374, 1915. (New synonymy.)
Osmoderma caviceps Casey, Mem. Col. 6: 374, 1915. (New synonymy.)
Osmoderma caviceps lacustrina Casey, Mem. Col. 6: 374–375, 1915. (New synonymy.)
Osmoderma scabrum Caseyi Schenkling, Coleop. Cat., p. 9, 1922. (New synonymy.)

Male.—Median length from anterior edge of pronotum to apex of pygidium 14.5 to 23 mm.; greatest width of elytra 8 to 13 mm.

Vertex, front, and clypeus black to piceus, shiny; vertex with moderately coarse, deep, confluent punctures except apically smooth with scattered punctures; front deeply concave, superantennal prominences strong; clypeus broader than long, strongly reflexed and broadly rounded at apex, often feebly sinuate; front and clypeus with irregular confluent interlacing lines or annuli, punctured.

Pronotum black to piceus, occasionally with green metallic or cupreous luster, convex, about one-third wider than long; hexagonal, sides obtusely prominent at middle, straight or slightly sinuate to base or apex; surface with four distinct subanterior ridges, the medial two of which are longest and most prominent; punctures coarse and deep, close-set anteriorly and laterally, separated subbasally from one to two times their own diameter. Scutellum large, triangular, usually with scattered, moderately coarse punctures.

Elytra black to piceous, often with cupreous sheen; oblong, about a fourth longer than wide and a third wider than pronotum, broadly arcuate laterally; disk flat or feebly convex; with moderate to coarse anastomosing vermiculate rugae, among which longitudinal striae may be present, particularly near the suture; striae and hollows between the rugae with small feeble annuli.

Pygidium triangular, transverse, strongly convex; basal margin densely and minutely rugulose, opaque; scattered crescentiform punctures caudad, nude.

Fore tibiae tridentate, inner spur present; middle and posterior tibiae with five teeth and two apical spurs.

Male genitalia as shown in figure 1. Small variations in the shape of the distal portion of the male parameres have been observed in specimens reared from the same source, in individuals obtained from widely separated parts of the range of the species, and in specimens

collected from a given microhabitat. Since these small differences cannot be correlated with invariable external characters, they undoubtedly fall within the scope of species variation. The genitalia of this species are easily distinguished from those of *eremicola*.

Female.—Median length from anterior end of pronotum to apex of pygidium 15.5 to 23 mm.; greatest width of elytra 8.5 to 14 mm.

Vertex, front, and clypeus almost flat on upper surface, rugose; clypeus never strongly reflexed at apex.

Pronotum moderately convex; the four subanterior ridges present but less prominent than in the male.

Pygidium more pointed and less convex than in the male, usually punctate and irregularly rugulose, pubescent.

Female genitalia illustrated in figure 3. The inner sclerites vary a little in shape but as a whole the internal genitalia are remarkably constant.

Type.—The location of the type of *Trichius scaber* is not definitely known. According to Horn (9, 10), part of the coleopterous collection of Palisot de Beauvois went from A. Chevrolat to Neervoot Van de Poll, the Cetoniidae of the latter to O. E. Janson, while Janson's cetoniid collection of the world went to F. T. Valck Lucassen. Because of the inaccessibility of this type and since the original description based on a male specimen from Pennsylvania by Beauvois seems adequate, no attempt has been made to secure the type or to have specimens compared with it.

In 1837 Kirby described *Trichius* (*Gymnodus*) *rugosus* and *T.* (*Gymnodus*) *foveatus*, the specimens having been obtained from Nova Scotia. As pointed out by Burmeister and Schaum (1840) and later writers as well, the former was a female and the latter a male of *scabra*.

Bainbridge (1841) described *Osmoderma Beauvoisii* from specimens supposedly obtained from equinoctial Africa. According to Schaum (1844), the specimen was from North America and had been considered by Gory and Percheron as the female of *O. scabra*. Schaum considered *Beauvoisii* a synonym of *O. rugosa* in this paper. Later, in 1849, after a trip to the United States, he considered both specific names as synonyms of *scabra*.

In 1915 Casey described several new species and subspecies in this genus, delimiting them because of differences in size, color, and punctation. I have studied his types and descriptions critically, as well as many specimens from widely separated parts of this country, dissecting the genitalia of the type specimens as well as many others, and have come to the conclusion that all those described under his so-called *scabra* section must

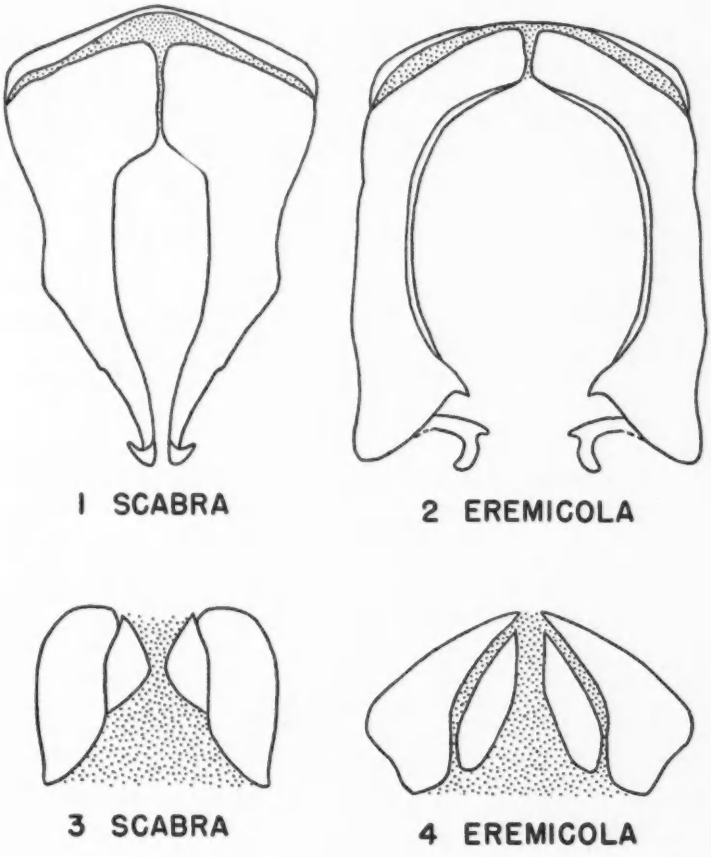

Fig. 1. *Osmoderma scabra* (Beauvois). Male parameres.
Fig. 2. *Osmoderma eremicola* (Knoch). Male parameres.
Fig. 3. *Osmoderma scabra* (Beauvois). Female genitalia.
Fig. 4. *Osmoderma eremicola* (Knoch). Female genitalia.

All drawings were made by the author (×23). A dorsal view of the male parameres and a ventral view of the female genitalia are shown for each species.

fall as synonyms of that species. As shown by Casey, variations in color and punctation occur frequently; however, they show no constancy in specimens from either a small or a large geographical area. These variable external differences have been seen within a series of specimens reared from a single tree or stump, which, in each case, probably contained the progeny resulting from the deposition of a single female. These rearings were carried to completion in the laboratory, the original material having been obtained in Minnesota and Massachusetts. A study of both the male and the female genitalia, on the other hand, revealed excellent characters which were constant enough to fall within the range of variation of a species.

Data on these Casey types, all of which are housed in the United States National Museum, follow: *Osmoderma delicatula:* Type, male, U. S. N. M. Catalogue No. 48711, Paris, Maine. *Osmoderma scabra gracilipes:* Type, female, U. S. N. M., Catalogue No. 48712, Cedar Lake, Wis. *Osmoderma scabra rugosa* (*Osmoderma scabra caseyi* Shenkling) Type, male, U. S. N. M. Catalogue No. 48713, Inglenook, Pa. (Champlain); paratype, male, New York; paratype, male; paratype, male, Wingdale, N. Y. *Osmoderma caviceps*: Type, male, U. S. N. M. Catalogue No. 48714, Milwaukee County, Wis., August 24, 1906. *Osmoderma caviceps lacustrina:* Type, male, U. S. N. M. Catalogue No. 48715, Wisconsin; paratype, male, Randall, Burnett County, Wis., August 5–7, 1909; paratype, male, Wisconsin. Colonel Casey also gave a manuscript name, *Osmoderma nigra*, to a female specimen of this genus collected on his farm in Rhode Island. This species, too, equals O. *scabra*.

Comparative Notes.—The pronotal ridges and the general coarse sculpture readily distinguish this species from *eremicola*.

Distribution.—Nova Scotia, New Brunswick, Quebec, Ontario, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Michigan, Indiana, Ohio, Kentucky, Tennessee, Wisconsin, Illinois, Minnesota, Iowa, and Kansas.

2. **Osmoderma eremicola** (Knoch)

Cetonia eremicola Knoch, Neue Beytr. Insectenkunde, pp. 105–109, pl. 2, fig. 1, 1801.
Trichius eremicola Say, Jour. Acad. Nat. Sci. 3: 240–241, 1824.
Osmoderma eremicola Gory and Percheron, Mon. Cet., pp. 47, 77, pl. 8, fig. 3, 1833; Burmeister and Schaum, *in* Germar, Zeitschr. Ent. 2: 383, 1840; Castelnau, Hist. Nat. Col. 2: 159, 1840; Burmeister, Hand. Ent. 3: 714, 1842; Fletcher,

Ann. Rept. Ent. Soc. Ontario for 1879, p. 71, 1880; Benderitter, Miscl. Ent. 4(8): 97–98, 1896; Davis, Roger Williams Park Mus. Bull. 1: 33, 1904; Bedel, L'Abeille 30: 256, 1906; Leng, Jour. N. Y. Ent. Soc. 18(2): 77, 1910; Blatchley, Col. of Indiana, pp. 1001–1002, fig. 419, 1910; Casey, Mem. Col. 6: 375–376, 1915; Davis, Jour. Econ. Ent. 9(2): 267, 1916; Dawson, Nebr. Univ. Studies 22: 137, 1922; Hayes, Illinois Biol. Monogr. 12(2): 70–71, 1929; Böving and Craighead, Ent. Amer. 11: 260, pl. 87, 1931; Sim, U. S. Dept. Agr. Circ. 334: 10–11, fig. 3, 1934.

Osmoderma eremicola subplanata Casey, Mem. Col. 6: 376, 1915. (New synonymy.)

Osmoderma montana Wickham, Proc. Ent. Soc. Wash. 22(9): 233–234, 1920. (New synonymy.)

*M*ale.—Median length from anterior edge of pronotum to apex of pygidium 16.5 to 28 mm.; greatest width of elytra 10 to 15.5 mm.

Vertex, front, and clypeus black or rufo-piceus; vertex with a transverse, somewhat arcuate callus, smooth or sparsely punctate; front somewhat deeply concave, superantennal prominences strong, clypeus broader than long, strongly reflexed and broadly rounded at apex; front and clypeus with close sculpture of fine interlacing lines, annuli, or rugae arranged transversely, punctured.

Pronotum black, rufo-piceus, or mahogany brown, shiny; strongly convex, about one-third wider than long; hexagonal, straight or slightly sinuate to middle or beyond, then converging and arcuate to apex; surface with a large, deep, transverse concavity before the middle, with its anterior margin transversely prominent and cariniform, continued posteriorly for a short distance deeply, and then more shallowly by a medial impression near or to the base; coarse crescentric punctures with yellowish hairs moderately close anteriorly, fine, sparse, and nude caudad. Scutellum large, triangular, with moderate or coarse punctures.

Elytra black, rufo-piceus, or mahogany brown; oblong, about a fourth longer than wide, broadly arcuate laterally and rounded apically; surface feebly and subevenly convex, smooth except for rugulose margins, with moderately close, fine punctures arranged in striae beside suture; often a transverse incision at each side from the suture near the apex of the scutellum.

Pygidium triangular, transverse, strongly convex; sparsely punctate with crescentric punctures arranged concentrically, nude.

Fore tibiae tridentate, inner spur present; middle and posterior tibiae with five teeth and two apical spurs.

The general shape of the male parameres is shown in figure 2. As with the other species, small variations occur in the shape of the distal parts.

Female.—Median length from anterior end of pronotum to apex of pygidium 18.5 to 29 mm.; greatest width of elytra 10 to 16 mm.

Front and clypeus almost flat on upper surface, rugose; clypeus not at all or only slightly reflexed at apex.

Pronotum moderately convex; transverse concavity before the middle smaller and not so deep as in the male, anterior margin less prominent, concavity not continued posteriorly along the median line.

Pygidium more pointed and less convex than in the male; densely punctate and irregularly rugulose; pubescent.

The uniform and characteristic genitalia of the female are illustrated in figure 4.

Type.—Horn (9) states that the coleopterous collection of A. W. Knoch went to the Zoological Museum of Berlin, so it is likely that the type of *Cetonia eremicola* resides there. No effort was made to secure the type or to have specimens compared with it inasmuch as Knoch's excellent original description clearly segregates this North American species.

In 1915 Casey (3) described as new *Osmoderma eremicola subplanata* from a single example purported to differ from the typical *eremicola* in shape, color, and sculpture. It is my contention that these differences all fall under the variations expressed by the species *eremicola*. Such variations are readily noted in specimens reared from a single source as well as in a long series of museum specimens representative of diverse localities. A study of the genitalia of the type showed that they did not differ significantly from other individuals of this species. Therefore, *subplanata* must be suppressed as a synonym of *eremicola* (Knoch). The type of *subplanata*, a female collected at Saint Louis, Mo., is in the United States National Museum. It bears Catalogue No. 48710.

In 1920 Wickham (17) described a new species, *Osmoderma montana*, from a single specimen. This type, which is also in the United States National Museum, bears the following data: Holotype, female, U. S. N. M. Catalogue 23728, 18 miles south of Dry Creek, Mont., June 20, 1919 (M. A. Hanna). This coleopterist believed that the genitalia of the Montana specimen were rougher and more grooved than those of a Wisconsin example of *O. eremicola;* otherwise, on the basis of the superficial external characters found, he would not have given the Montana specimen a name. I studied this specimen carefully and determined it to be conspecific with *eremicola*. It should be pointed out that the genitalia of the latter species also vary a little in different specimens, but this does not justify splitting them into species.

Comparative Notes.—The characteristically deep pronotal concavity and the generally smooth sculpture readily separate this species from *scabra*.

Distribution.—Quebec, Ontario, Manitoba, Alberta, Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, West Virginia, Virginia, South Carolina, Georgia, Michigan, Indiana, Ohio, Kentucky, Wisconsin, Illinois, Minnesota, Iowa, Missouri, Arkansas, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Montana.

Except for Rhode Island, South Carolina, Georgia, and Nebraska, the above distribution is based upon specimens

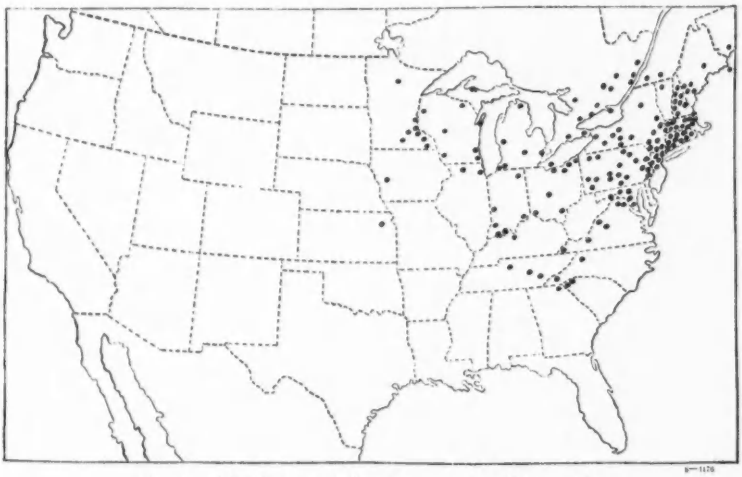

Fig. 1. Distribution of *Osmoderma scabra* (Beauvois).

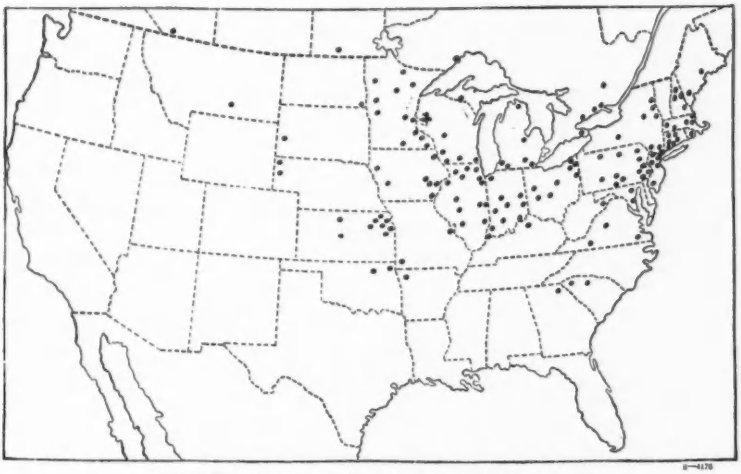

Fig. 2. Distribution of *Osmoderma eremicola* (Knoch).

examined during the course of this study. Davis (1904) records that *eremicola* occurs occasionally in Rhode Island during July.

Mr. O. L. Cartwright (in correspondence) states that he has seen specimens from South Carolina and kindly furnished the following locality records: Greenville, May 17, 1930 (H. K. Townes, Jr.); York County, 1931 (Miss Louetta Youngblood). In 1910 Leng recorded the collection of *eremicola* by Dury the last two weeks of June, 1909, Rabun County, Georgia. Dawson (1922) examined specimens from Nebraska collected at the following localities: Warbonnet Canyon, Sioux County, July; Monroe Canyon, August 27, 1908 (C. H. Gable).

ACKNOWLEDGMENTS

Many individuals and institutions have aided me in this study. Therefore, my appreciation and gratitude are hereby expressed:

To Dr. E. A. Chapin of the Smithsonian Institution for his interest and advice throughout the progress of the work. To Messrs. C. W. Collins, T. H. Jones, and R. T. Webber of the Morristown, N. J., laboratory of the Division of Forest Insect Investigations, for suggestions and encouragement. Over forty friends in charge of collections at nearly as many institutions have contributed of their time in furnishing material and information which have made this study at all worth while. I thank these and wish there were space for individual mention.

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PERSPECTIVES IN BIOCHEMISTRY, THIRTY-ONE ESSAYS PRESENTED TO SIR FREDERICK GOWLAND HOPKINS BY PAST AND PRESENT MEMBERS OF HIS LABORATORY. Edited by JOSEPH NEEDHAM and DAVID E. GREEN, ix+361 pages, 6 pls. and numerous figures and diagrams. 1938. 5.75 x 9 inches. Published by the CAMBRIDGE UNIVERSITY PRESS, 60 Fifth Ave., New York City. Price, $4.75.

The present essays were presented to Sir F. G. Hopkins on the occasion of his seventy-fifth birthday. "The aim of the writers has been to indicate the most promising lines of advance in the various fields which they survey . . . and to speculate a little on the likely paths of future thought and discovery." As one of the authors expresses it, "The essays were to be suggestive and provocative."

This volume will interest anyone who has curiosity concerning the chemistry of living matter. It is so simply written any biologist can follow the various discussions. As it is a series of discrete essays by as many different authorities, the only connecting thread being that all are in the same general field, it is a volume which can be read an essay at a time. It is one of those books in which one enjoys reading a few pages before dropping off to sleep. We cite it to those entomologists who work with the chemistry of insects, plants, insecticides and fungicides. Only one article has direct bearing on entomology and that is "The Chemical Regulation of Insect Growth" by V. B. Wigglesworth of the University of London, School of Hygiene and Tropical Medicine. Wigglesworth, because of his work in insect physiology, needs no introduction to entomologists. Here he reviews his work on the blood-sucking *Rhodnius prolixus* of South America, which in studies of growth at ecdysis and in metamorphosis is an ideal subject because it needs only one meal of blood between moults. Moulting can be timed.

The volume opens with "The Biochemistry of the Individual" by J. B. S. Haldane. We have not space to list all, but some that interested the reviewer are, "Recent Developments in our Knowledge of the Protein Molecule" by Dorothy J. Lloyd, "Proteins and Cell Organization" by R. A. Peters, "Molecular Forces, Orientation and Surface Films" by N. K. Adam, "Respiratory Carriers" by Malcolm Dixon, "Recent Accomplishments in Carbohydrate Chemistry" by D. J. Hall, "Biochemistry and the Pathogenic Viruses" by Barbara Holmes, "Chemical Cycles in Muscle Contraction" by Dorothy M. Needham, and "Chemical Aspects of Morphogenetic Fields" by Joseph Needham.

We wish that more of our graduate students could be interested in this type of "outside reading." In the reviewer's day, in western universities, the graduate course had not been evolved. All graduate work was of undergraduate courses, reading and research. Reading was a requirement but such a privilege and pleasure that spare time was about equally divided between field trips and reading. Now the so-called graduate courses crowd in until the student fears he will miss organized knowledge altogether if he glances outside of his appointed schedule. The pressures and basic points of view have changed and are in the reviewer's opinion highly questionable. The present high pressure graduate course turns out a staff collector-of-information. The earlier more nearly self-educated type of scientific investigator was more independent in research and did less clock watching.—C. H. K.

RESPONSES OF THE BLOWFLIES, COCHLIOMYIA AMERICANA C. & P. AND PHORMIA REGINA MEIGEN, TO STIMULATIONS OF THE TARSAL CHEMORECEPTORS

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The purpose of these experiments was to study the function of the gustatory chemoreceptors of the blowflies, *Cochliomyia americana* C. & P. and *Phormia regina* Meigen. The gustatory sense organs of *P. regina* have been previously studied and reported on by Minnich (1926). Studies on the chemoreceptors of the tarsi and mouth parts of the primary screwworm fly, *C. americana*, which are gustatory in function, are here reported on for the first time. The tests on the adults of these species cover the normal responses to sucrose, responses to sucrose with mercuric chloride added, effects of age, and effects of sex on these responses.

MATERIALS AND METHODS

The larvae of *C. americana* were reared in a live rabbit. The larvae of *P. regina* were reared on lean beef in pint fruit jars. Larvae of both species pupated in sand; and as the adults emerged, they were transferred to clean screen cages and offered water until used for testing.

In tests made on individual flies, the experimental animals were chilled and mounted on cubes of beeswax according to the procedure outlined by Deonier and Richardson (1935). On recovery from the chilling the flies were divided at random into groups of ten. The flies in a group were tested first on water, then on a 1 molar sucrose solution to obtain the responses of the flies to sucrose alone. The proboscis was not permitted to touch the sucrose solutions. Blowflies normally extend their proboscis when the chemoreceptors on the tarsi are stimulated by sucrose solutions or other attrahents; this furnishes a criterion for determining the reaction of the flies to test solutions. As the flies were tested in consecutive order, each insect was allowed to rest while the other individuals in the series were being tested. The same flies were then used in obtaining the responses to sucrose solutions containing mercuric chloride. Water was again offered immediately preceding the trials with the test solutions. This not only checked on the water-satiated condition of the flies, but also washed off any sucrose solution that might have been present from the previous trials with sucrose.

[1]The writer is indebted to Dr. C. H. Richardson for his suggestions and criticisms.

The criterion for measuring the reaction of the flies to test solutions given by Deonier (1938) was followed in these experiments. If a solution initiated responses of the proboscis, a further observation was possible on the effects of the mercuric chloride on the chemoreceptors located on the proboscis. A definitely negative response to stimulations of the chemoreceptors on the proboscis caused instant withdrawal of the mouth parts.

The number of flies responding to various concentrations of sucrose was obtained by testing each fly on a series of dilutions of 0.001 molar to 1.0 molar, beginning with the 0.001 molar concentration and progressing to the next higher concentration in the series.

When the tests were made with mercuric chloride in sucrose solution, the sex of the fly was recorded so that the data could be reclassified to obtain the effects of sex on the responses to gustatory stimulations.

Since the flies mounted on the beeswax cubes were tested under conditions which were unnatural for the flies, it was desirable to know what effects concentrations of toxic compounds, that were repellent to the mounted flies, would have on free flies. To determine the reaction of unmounted flies, tests were conducted on *C. americana* and *P. regina* at Tempe, Arizona, during the spring and summer of 1938. Tests were made on *P. regina* during each of the following months: April, May, June, and July.

In the first series of tests, three identical screen wire cages 10x10x10 inches were used. Each cage was provided with small glass dishes, 1½ inches in diameter and ¼ inch deep, which contained the solutions to be tested. Absorbent cotton pads were placed in the dishes to prevent the flies from drowning in the solutions. Cage 1 was a sucrose check in which the flies had access to a 1.0 molar sucrose solution; cage 2 contained two dishes, one of 1.0 molar sucrose and the other mercuric chloride (2 g./100 cc.) in a 1.0 molar sucrose solution; cage 3 contained a dish of mercuric chloride (2 g./100 cc.) in 1.0 molar sucrose. In the later series a fourth cage was added. In series 3 a water check was added, and in series 4 no food or water was given the flies. The flies were 24 hours old at the beginning of these experiments.

The cages were kept in the open but in the shade of a building, since the summer temperatures in the direct sunlight at Tempe are so high that flies often become inactive during the heat of the day. *Phormia regina*, when in the sunshine, were observed to become quiescent as the air temperatures approached 100 degrees F. The solutions were kept fresh to prevent a concentrating of the compounds offered, due to evaporation of the water. Detailed observations were made on the activity of flies and their reactions, when they came in contact with the various solutions.

RESULTS

Responses of flies to sucrose solutions.—Both *C. americana* and *P. regina* extended their proboscis when the chemoreceptors on the tarsi were stimulated with 1 molar sucrose solutions. At a concentration of 0.25 molar or above, from 92.0 per cent to 100 per cent of the *C. americana* gave positive responses. As the concentration of sucrose

was decreased below 0.25 molar, there was a gradual decrease in the number of flies that would respond. The threshold for some individuals to sucrose was lower than 0.001 molar. It was observed when making tests that the *C. americana* used in these experiments, which had been without food for 48 hours, were beginning to weaken and many were beginning to die of starvation.

P. regina were more resistant to a starvation period. The responses of these flies to sucrose increased as the flies became older and food was withheld. For flies 24 hours of age 84.5 per cent responded to 1 molar sucrose; 94.0 per cent responded for those that were 48 hours old.

TABLE I

RESPONSES OF *Cochliomyia americana* C. & P. AND *Phormia regina* MEIGEN TO SUCROSE AND TO MERCURIC CHLORIDE IN SUCROSE SOLUTION

Age of Flies Hours	Number of Flies Tested	Responding to Sucrose Check	Concentration of Sucrose in Moles	Concentration of Mercuric Chloride (g./100 cc.)	Number of Flies Responding to Sucrose With Mercuric Chloride Added		Number of Flies Ingesting Toxic Solution
					Chemoreceptors on Tarsi Stimulated	Chemoreceptors on Proboscis Stimulated	
C. americana:							
24	70	69	1.0	2.00	21	0	0
	100	93		1.00	51	14	4
24	50	50	0.5	1.00	13	0	0
	100	100		0.50	84	45	28
P. regina							
24	50	47	1.0	2.00	11	0	0
	50	44		1.00	17	5	0
	50	40		0.50	20	13	9
	50	41		0.25	25	18	14
48	100	92	1.0	2.00	42	16	1
	100	92		1.00	40	22	3
	100	95		0.50	68	51	43
	50	48		0.25	49	45	42

Responses to mercuric chloride in sucrose solutions.—The effects of mercuric chloride in sucrose solutions on the chemoreceptors of *C. americana* were studied. Mercuric chloride was very repellent to day-old *C. americana* at concentrations of 1.0 per cent or above. A few of the flies, however, gave positive responses when the chemoreceptors on the proboscis were stimulated. At 2.0 per cent concentration of mercuric chloride, the proboscis was immediately withdrawn from the test solution in every instance that stimulations of the tarsal chemoreceptors initiated responses.

A series of tests were made on *C. americana* with 1.0 per cent and 0.5 per cent mercuric chloride in 0.5 molar sucrose solutions. Complete

data for comparison over a wide range of concentrations are not available, but these tests indicate that the mercuric chloride was more repellent in lower concentrations of sucrose.

A more complete series of tests were made with *P. regina*. Mercuric chloride was less repellent to the flies which were 48 hours of age than to those that were 24 hours of age. Concentrations as low as 0.25 per cent of this poison in sucrose were definitely repellent to flies 24 hours old. The flies 48 hours old were not repelled, but the feeding responses were

TABLE II

RESPONSES OF *Cochliomyia americana* C. & P. AND *Phormia regina* MEIGEN TO MERCURIC CHLORIDE IN SUCROSE SOLUTION ACCORDING TO SEX

Age of Flies in Hours	Sex	Number of Flies Tested	Number Responding to 1 Molar Sucrose	Concentration of Mercuric Chloride (g./100 cc.) in 1 Molar Sucrose	Number of Flies Responding to Sucrose With Mercuric Chloride Added		Number of Flies Ingesting Toxic Solution
					Chemoreceptors on Tarsi Stimulated	Chemoreceptors on Proboscis Stimulated	
C. americana							
24	Female	48	47	2.0	16	0	0
	Male	22	22		5	0	0
24	Female	35	33	1.0	18	7	1
	Male	65	60		34	7	3
P. regina							
24	Female	29	28	2.0	9	0	0
	Male	21	19		2	0	0
24	Female	26	23	1.0	9	3	0
	Male	24	21		8	2	0
48	Female	53	49	2.0	22	10	0
	Male	47	43		20	6	1
48	Female	48	46	1.0	20	11	2
	Male	52	46		20	11	1

slightly lowered by the presence of the poison. The results of these tests are given in Table 1.

The sex of the individual flies was recorded in part of these tests, in order that the data could be reclassified to determine if there were any differences in the responses due to difference in sex. These data are given in Table II. It was concluded from these data that sex difference was not an important variable in the populations under consideration. These data agree with those of Minnich (1929), who did not find a difference in responses attributable to sex in *Calliphora vomitoria* Linn.

Results of cage tests.—The flies in cage 1 were observed to feed freely on the 1.0 molar sucrose solution. This cage served as a check on the death rate of fed flies.

TABLE III

RESULTS OF CAGE TESTS ON THE RESPONSES OF *Cochliomyia americana* C. & P. AND *Phormia regina* MEIGEN TO MERCURIC CHLORIDE (2 g./100 cc.) IN SUCROSE SOLUTIONS

Series Number	Cage Number	Solutions Offered	Accumulated Total Dead after					Number Living at End of Experiment	Total
			12 Hours	24 Hours	36 Hours	48 Hours	60 Hours		
C. americana	1	Sucrose....	5	12	14	14	.....	162	176
	2	Sucrose & sucrose + $HgCl_2$.....	4	10	23	23	.....	83	106
	3	Sucrose — $HgCl_2$.....	8	30	64	65	.....	0	65
P. regina I	1	Sucrose....	0	1	1	1	1	158	159
	2	Sucrose & sucrose + $HgCl_2$.....	0	0	1	3	23	125	148
	3	Sucrose — $HgCl_2$.....	4	11	24	65	96	3	99
II	1	Sucrose....	5	10	10	.....	.....	257	267
	2	Sucrose & sucrose + $HgCl_2$.....	11	16	21	.....	.....	159	180
	3	Sucrose — $HgCl_2$.....	109	206	220	.....	.....	7	227
III	1	Sucrose....	17	28	33	33	33	325	358
	2	Sucrose & sucrose + $HgCl_2$.....	31	47	51	58	59	204	263
	3	Sucrose — $HgCl_2$.....	89	273	277	.....	.....	0	277
	4	Water.....	61	71	126	258	356	47	403
IV	1	Sucrose....	2	6	9	10	10	178	188
	2	Sucrose & sucrose + $HgCl_2$.....	4	11	16	18	21	183	204
	3	Sucrose — $HgCl_2$.....	183	194	198	.....	.....	0	198
	4	None.....	110	137	146	.....	.....	0	146

In cage 3 the flies, which only had access to a sucrose solution containing 2 per cent mercuric chloride, refused to feed. Individuals would come to the dish repeatedly, but were repelled as soon as their tarsi touched the toxic solution. In the last stages of inanition a few of the flies would attempt to feed. Flies that were in this weakened condition

would have the proboscis partially or entirely extended continuously. Death to all the flies occurred within 60 hours; except in a test conducted during March, when weather conditions were such that a few individuals were able to survive for 3½ days from time of emerging without food or water. Death was due to starvation, and not to the mercuric chloride in the solution which was offered.

In cage 2 the flies had a choice of a toxic and a non-toxic source of food. The flies were observed to refuse the dish containing the poison, which they detected through the chemoreceptors on the tarsi. A few flies would momentarily extend their proboscis, but none were observed to feed. Contact with the toxic solution was made either by individuals in walking about the cage, or when in flight they accidentally alighted on the dish.

A higher percentage of the flies in cage 2 died than did those in the check cage. Some of the flies that came in contact with the mercuric chloride may possibly have ingested enough of the poison to kill them either when cleaning their appendages; or by feeding on the sucrose solution, and ingesting with it some of the poison solution that remained on their appendages.

Blowflies that are kept in a cool place can survive for relatively long periods without food or water. Keeping the flies in darkness, which causes them to be quiescent, also tends to lengthen their lives. The effects of high temperatures are indicated in the tests on *P. regina*. The death rate was greater, and the effects of starvation more rapid in tests conducted during the summer months. These facts will explain what appears to be a lack of homogeneity in the results for the various tests. In the experiments conducted during warm weather, the absence of water caused rapid death of the flies within a few hours. The number dying in the cage, containing no food or water, parallels closely that of the cage containing mercuric chloride in sucrose solution.

Access to water reduced the death rate, and enabled a part of the flies to survive the test period without food. These checks show that death of the flies in poison cages was due to starvation for food and water, and that 2.0 per cent mercuric chloride has a repellent effect comparable to that found in tests with mounted flies. A summary of these data on cage tests are given in Table III.

SUMMARY

1. *C. americana* were found to have on the tarsi and proboscis gustatory chemoreceptors through which non-volatile substances, such as sucrose and salts, can be detected.

2. Mercuric chloride was more repellent to *C. americana* in 0.5 molar sucrose than in 1.0 molar sucrose. Mercuric chloride was less repellent to *P. regina* which were 48 hours of age than to those that were 24 hours of age. *P. regina* 48 hours old were not repelled by a 0.25 per cent concentration of this poison in sucrose solution; but the feeding responses were slightly lowered by the presence of the toxic substance.

3. Sex difference was not an important variable in the responses given to test solutions by the blowfly populations studied.

4. From the results of cage tests, it was concluded that the responses of free blowflies were comparable to the responses of flies that had been subjected to the mounting procedure. The flies were found to select discriminately solutions to be fed upon through chemoreceptors on the tarsi. They died of starvation when 2 g./100 cc. of mercuric chloride in sucrose solution was the only source of nourishment and water. The death rate was higher, and the effects of starvation were rapid in cage tests conducted during the summer months.

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Deonier, C. C. 1938. Effects of Some Common Poisons in Sucrose Solutions on the Chemoreceptors of the Housefly *Musca domestica* L. Jour. Econ. Ent. 31 (6): 742–745.

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1929. The Chemical Sensitivity of the Legs of the Blow-fly, *Calliphora vomitoria* Linn., to Various Sugars. Zeitschr. f. Vergl. Physiol. 11 (1): 1–55.

ENTOMA, A DIRECTORY OF INSECT PEST CONTROL, edited by C. C. HAMILTON. Third edition. Pages 1–170, 9x6, paper; 1939. Published by the Eastern Branch of the American Association of Economic Entomologists. Obtainable by non-members of this Association from C. C. Hamilton, Dept. of Entomology, N. J. Agri. Exp. Sta., New Brunswick, N. J. Price $1.00.

To the few economic entomologists who have not already received copies of Entoma and who by chance should read the ANNALS notice is hereby given that the third edition has appeared, bigger and better than ever. Briefly, it tells the busy entomologist where to buy materials, equipment or services. It contains an excellent outline of information on insecticides and fungicides and their uses. The numerous advertisements are educational as well as useful to the buyer. New sections include: table of estimated consumption of insecticides and fungicides, list of trademarked insecticides, fungicides and adjuncts, and list of the principal manufacturers of these materials. C. C. Hamilton and associates and the Eastern Branch are performing a splendid service to all who are concerned in any way with insect pest control. We hope that Entoma will appear in the future with the regularity and dependability of the telephone directory.—F. L. C.

EVOLUTIONARY TRENDS IN CADDIS WORM CASE CONSTRUCTION

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Discussion of the probable ancestry of insects is usually based upon two types of study—investigation of the fossil record, and detailed examinations of body structure—phases of palaeontology and comparative anatomy. Such considerations usually begin with the first subdivisions of the class Insecta and conclude with the derivation of the various orders.

Among other groups of animals and among plants, further fields of study have been scoured for information pertaining to the relationships between organisms. Most of these are as yet untried where insects are concerned. It is not possible to procure in the living condition sufficient numbers of several closely related species to use serological investigations to check suspected relations, and such small specimens are difficult to handle in this exacting technique. Distributional data are not of great value when only parts of any group are as yet recognized. Insufficient information is at hand to recognize many vestigial organs in insects, so that this field is still relatively barren, at least for subordinal considerations. So little is known of comparative insect embryology that no present help can be sought in that direction. Physiological processes in insects are poorly understood, their implications scarcely more than suggested. And in trichopterous fossils, the wing hair matted over the veins prevented the imbedding matrix from reaching them. Hence the venational characters so largely relied upon by palaeo-entomologists are mostly obscured.

The suborders of insects are usually considered of phylogenetic importance. Following the erection of the order Trichoptera by Kirby (in a footnote to a paper on Strepsiptera, 1813), Kolenati prepared a very useful analysis of the order (1848, 1859) and divided it into two on the basis of the structure of the maxillary palpi. "Aequipalpia" included those families in which the palpi had the same number of segments in both male and female, and "Inaequipalpia" comprised the Phryganeidae, Limnephilidae and Sericostomatidae of our present

classification, forms with dimorphic palpi. This separated groups whose phylogeny has been unquestionably close, but did not satisfy later workers. More recently, Martynov (1924) used "Integripalpia" and "Annulipalpia" to segregate those forms in which the last segment of the maxillary palpus is entire from those in which it is secondarily annulated. Since the presentation of these mutually incompatible viewpoints, published discussion concerning the subdivision of the order was discontinued.

The morphologists have also given some attention to Trichoptera. Krafka (1923, 1924, 1926), studying the chaetotaxy of the body, the morphology of the head, the structure of the prolegs, and the variations of the occipital suture, all in larval forms, concluded that Leptoceridae (Aequipalpia, Integripalpia) were most primitive, that the phryganeid complex (all of the Inaequipalpia, most of the Integripalpia) were modified in one direction, while the remaining Integripalpia and the Annulipalpia were derived from a second branch. This latter category includes the Rhyacophilinae, a subfamily around which much discussion has centered. Comstock and Needham (1898) and their followers (Tillyard, 1917, 1918, 1919; Comstock, 1918; Martynov, 1924; Betten, 1934) have placed their faith upon adult venational characters. Since the genus Rhyacophila has wing veins which most closely correspond to the Comstock-Needham hypothetical venational diagram, it was considered to be the archetype of the order, with the Leptoceridae much more highly organized (Text-figure 1.). Neither view has been further elaborated.

GROUPS OF RELATED FAMILIES

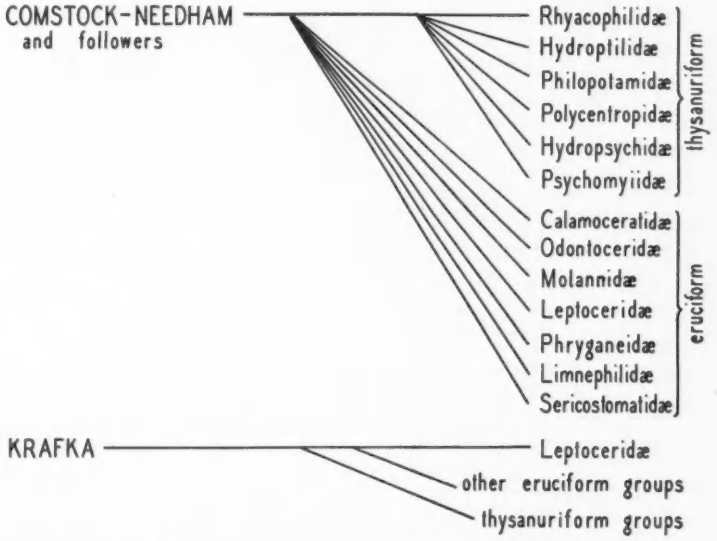
At present, a number of family groups are recognized but little attempt has been made to relegate these to subordinal rank. The Phryganeidae and Limnephilinae (Limnephilidae) are undoubtedly close, with Apataniinae (Limnephilidae) as an offshoot, perhaps in the direction of Goerinae (Sericostomatidae). The sericostomatids other than Goerinae are rather loosely related, and probably result from convergence of distant groups, as has often been suspected (McLachlan, 1876; Ulmer, 1907, 1909, 1912; Betten, 1934). These three families, however, are sufficiently similar that Kolenati (1848) did not go far astray in segregating them as Inaequipalpia.

The family Hydropsychidae is an interesting nucleus of another family group. Via the genus Diplectrona, it is so closely related to Parapsyche (Arctopsychidae) that it would probably be well to recognize subfamily Arctopsychinae rather than accord the group full family rank. Macronematinae (Hydropsychidae) is close to Hydropsychinae

but veers off to another side. Farther still is Psychomyiidae with subfamilies Psychomyiinae and Polycentropodinae, joined by Ross (1938).

Another family group centers around the Rhyacophilinae, with Glossosomatinae (Rhyacophilidae) tending toward Hydroptilidae (and perhaps thus approaching the Lepidoptera), with Hydrobiosinae (Rhyacophilidae) approaching Chimarrhinae (Philopotamidae) while the Rhyacophilinae (genus Rhyacophila) shows affinities for Philopotaminae.

Finally the Leptoceridae forms a complex closely akin to Odontocerinae and Calamoceratinae (Odontoceridae), and less obviously related to Molannidae and Beraeidae.



Phylogenetic schemes based on adult (above) and larval (below) morphology.

What factors could cause the order Trichoptera so to divide itself? Are there food habits or other features which parallel the present morphological family groups? We believe that the problem is not too complex to suggest an answer, even though systematists and morphologists have not found a satisfactory solution.

EVIDENCE ON PHYLOGENY FROM BEHAVIOR OF LARVAE

It was mentioned above that physiological investigations have not been very fruitful but they have been interesting. The most valuable of them concern the shelter construction exhibited prior to pupation by all larvae of Trichoptera. In a penetrating study by Dodds and Hisaw (1925), a very peculiar correlation was found between type of

shelter and rate of flow of the water in which the caddis worms lived, and certain suggestions were made relating the morphology of the larval sclerites to the environment. No hints were advanced however, towards an understanding of the phylogeny of the order, although further work in this direction was definitely needed.

Betten (1934) suggested that the case-building "habit arose in connection with the pupal stage, since what, on other points, are doubtless to be regarded as the lower forms do not have the cases until near the time of pupation." That is to say, that in Rhyacophilinae, the primitive development of the case (a stone chamber enclosing the most complete inner pupal cocoon found in Trichoptera) is retained, while in Leptoceridae and others, a derived condition exists, in that the larva builds the pupal case early in its life and lives in it until ready to metamorphose, never making an inner cocoon. This being true one might expect to find all gradations in the time of case-building commencement, but such is known in only a few Hydroptilidae. In all other forms, there are only two points in the life cycle when definite shelters are begun—just after hatching (in the case-bearing forms) and immediately before pupation (in the remaining types). These facts neither confirm nor disprove the hypothesis but lead to further search for pertinent evidence. It will be seen that Betten's theory is based upon the view that the Rhyacophilinae are primitive because they have the wing venation conforming closely to the diagram proposed by Comstock and Needham (1898). This almost requires that the habitat occupied by the larvae of Rhyacophila is that originally invaded by the ancestors of Trichoptera, and that case-bearing followed the same lines as classification of adults, family by family, regardless of habitat. But the larvae of Rhyacophilinae live only in fast streams, and there seems to be no answer to the query, "Why are there no naked caddis worms in ponds?" On the other hand is Krafka's phylogeny of Trichoptera (1924, 1925), with Leptoceridae as the most primitive family, which would not fit in well with any explanation of the origin of case-bearing.

However, something has been overlooked in these considerations. Perhaps the most characteristic feature of all immature Trichoptera is that they are a type of animal clinging to the bottom (benthos) and *always living in a current of water*. This current is of vital importance in understanding any caddis worm. The feature of these current dwellers which apparently disturbed Dodds and Hisaw was that caddis worms show none of the streamlining so regularly marking animals which habitually live in such niches. The cylindrical, blunt bodies of caddis worms are far from either the depressed or the oval form to be expected of them. Obviously then, these larvae do not live *in spite of* the current but rather *by means of* it. This distinction between an acquired tolerance and a definite benefit was hinted at by Dodds and Hisaw (1925) but its importance has not been further recognized. It is still customary to think of caddis worms living in brooks as occupying the same niche in the same way, as stonefly naiads, mayfly nymphs and other similar creatures. Yet they correspond more accurately to the blackfly (Simulium) whose larvae use the current as a respiratory and feeding aid and have become unable to gather food without it. Thus the hypognathus, eruciform larvae of Trichoptera and all pupae, make

the water which fills their cases flow caudad by an undulating movement in which the whole abdomen takes part. The water enters the front opening of the case and leaves by the rear aperture, being deprived of its oxygen en route, and by active larvae, of food particles as well. The prognathous thysanuriform caddis worms live in natural currents, clinging to rocks over which a river is running, and thus are not obliged to induce water flow for respiration and food. That they will do so if the current stops and hunger or an oxygen deficit stimulates them, is good evidence that the Trichoptera as a whole had this movement of the abdomen as a primitive larval characteristic. It definitely argues in favor of ancestral invasion of quiet water, as will be pointed out below.

EVIDENCE ON PHYLOGENY FROM ANATOMY AND FROM STRUCTURE OF LARVAL CASES

A number of structural differences have been pointed out between the caddis worms which produce their own current (eruciform type) and those which utilized the natural currents (thysanuriform type). These characteristics have been attributed to the different habitat occupied by the two larval types, the majority of the eruciform caddis being pond animals, most of the thysanuriform living in swift streams. This view does not explain the presence of case-bearing eruciform types in torrents or the existence of thysanuriform larvae in slow rivers, but when it is seen that both types actually live in a current at all times, the whole idea at once becomes completely untenable. The correlation is rather with the case-bearing habit, the precise history of which is obscure, even though all caddis worms build a case before they pupate.

Caddis worms must be regarded as secondarily aquatic, since the most primitive insects are terrestrial groups and apparently always have been. It would seem reasonable to assume that when the larval ancestors of Trichoptera went from land to water, it was to quiet water rather than into racing streams. Since all pond species build cases at the outset of their larval existence, as also do some of the rapid water forms, it might be postulated that the order as a whole developed the shelter-making habit either just before or immediately after migrating to the aquatic habitat.

The simplest shelter known in Trichoptera is, of course, no shelter. This is found only in the active stages of predaceous rhyacophilinids, whose behavior is very different from other caddis worms, and whose lack of a case might thus be thought a secondary loss, especially since their pupal shelters are very substantial affairs housing a complete silken cocoon. Such Psychomyiidae as Phylocentropus make the next simplest structure, this being a branching silken gallery tunnelled in the upper sand layer of slow streams. The resemblance to a burrow with reinforcement is striking. Perhaps the ancestral caddis worms first were fossorial forms, using a tube like that of Phylocentropus to cover their soft, caterpillar-like bodies. The old rule that "in its ontogeny, an organism recapitulates its phylogeny" might be invoked in the instance of Molanna and some other caddis worms which begin their sand cases as a tunnel, the walls of which they reinforce with silk, then free their product from the surrounding matrix (Copeland and Crowell, 1938).

Two serious disadvantages of this type of ancestral, diffuse, branching case would be ever present: Firstly, the difficulty met by the larva in forcing a current of water through such a large structure; secondly, the inflexibility of the shelter when the larva needed more food than came through its doorway. Abbreviation of the case would solve the first difficulty, and this has been done by virtually all caddis worms. To increase the amount of available food, four possibilities would be open, all of which have been taken by different groups of larvae. In fact, each solution of the problem is represented by a group of families which are closely related, i. e., a family-group. One way is to renounce the case completely and actively forage where food was plentiful and the natural currents were sufficient for respiratory needs—the behavior exhibited by modern rhyacophilinids. A second is to build a funnel at the opening of the silken gallery, to collect more food from the nearby slowly-moving water by a process akin to filtration and concentration—a method used by numerous other polycentropodinids. A third is to live upstream where the faster current would bring food to the doorway in greater quantity, and where, as for the rhyacophilinids, the respiratory needs would be no longer pressing. All other thysanuriform larvae are found in just this niche, a few having added a complexity by building excellent nets for snaring still more food. A fourth possibility is to free the shortened tube from the substratum and drag it around while feeding. This is the arrangement found in the herbivorous and scavenging families, much less active forms, whose heads show the hypognathous condition of present eruciform larvae. It is possible that the assumption of this head position was partly an adaptation for phragmotic closure of the anterior end of the case against attack by enemies there.

A good test for this hypothesis presents itself. If the factor which is correlated with the phylogeny of the Trichoptera is the method of solving a food and oxygen problem, then any radical difference in the mode of formation of a movable case might be expected only in a self-contained group not closely related to the others. Such a special type of movable case is that of Helicopsyche, a caddis worm which coils its lengthy shelter in a flat spiral, thus rendering it wieldy enough to drag about. As would be predicted in accordance with the theory above, Helicopsyche belongs to a category which even recently (Ulmer, 1907) was placed as *incertae sedis*, though many workers have classed it as an aberrant subfamily of Sericostomatidae (Ulmer, 1912; Martynov, 1912; Betten, 1934; Milne, 1936).

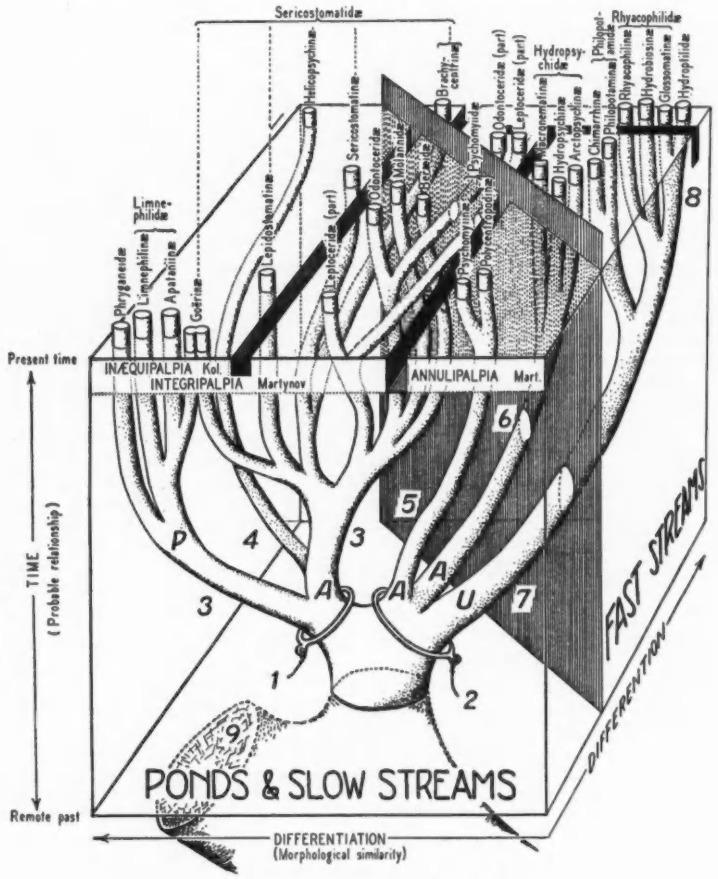
Extending the hypothesis, we would explain the presence of case-bearing larvae in faster streams on the basis of a secondary migration. These retained their cases but learned to wedge them between rocks (as do some Leptoceridae and many sericostomatids) or to fasten them between rocks (as do the Brachycentrinae of Sericostomatidae, and the few Odontoceridae found in such places). This migration is obviously a secondary one, since the only larvae in rapid water which bear cases are members of families all of which are case-builders. Since the ancestors of these families presumably had larvae which spent ages developing a good case to move about in quiet water, it might be predicted from the hypothesis that the few species from these groups which invaded

rushing streams would be much less perfectly adapted to conditions in the new environment than are the caseless forms which had occupied this precarious niche so much longer. This is borne out in fact, since the case-building caddis worms in fast streams have not yet learned to leave their houses when the water level in the stream drops, leaving them exposed to the air. They die of desiccation in this stranded position while the thysanuriform larvae desert their crude shelters and carefully woven nets to retreat within the water so necessary for their existence (Muttkowski, 1929). No more satisfactory instance of incomplete adaptation could be sought, since one of the commonest features of rapid water is the inconstancy of its level. Thus the case-bearing larvae can deal with one factor of their new environment, but their numbers are decimated annually by this other common characteristic. Incidentally, the families Leptoceridae and Sericostomatidae include most of the case-bearing forms in fast streams. The adults of both families show a highly specialized morphology, highest in the Sericostomatidae, which no longer have many pond-living representatives. Odontoceridae, closely related to the leptocerids, is also represented heavily in this niche.

To us it seems probable that the apparent exceptions to any explanation of case-building origin, family Hydroptilidae and subfamily Glossosomatinae (rhyacophilids), do not present an insurmountable obstacle. A modification of food preference might easily have split the ranks of the rhyacophilid stem and led some of the branches to develop anew the case-building habit, while still in the rapid stream habitat. In this instance, it would seem predictable that the time of case-building commencement would be variable, both within a species and between species, and that accessory structures might be expected to develop. The family Hydroptilidae is probably more closely related to Glossosomatinae than Glossosomatinae to Rhyacophilinae, and it is interesting to note that these two case-building groups not only show irregularity in the time of beginning a shelter, but also develop a different type of case. In these, the anterior and posterior ends of the case are not differentiated until just before pupation, and the larvae feed from both apertures. The hydroptilid larvae are more specialized in this direction than are the glossosomatinids, but the similarity in structure of both immature and adult specimens is obvious. Furthermore, in Rhyacophilidae and the closely related Philopotamidae, an inner cocoon of silk is developed before pupation, a feature found nowhere else in Trichoptera. These fulfillments of predictions give us more confidence in the theoretical outline.

SUMMARY

Plate I sums up our analysis of the problem. We suggest that one of the earliest differentiations in ancestral caddis worms, while they occupied their silken galleries in ponds and slow streams, was to become either carnivorous or to adopt the habits of vegetarians and scavengers. Because of this food preference, there was a reduction in the amount of acceptable food brought to their front doors by the current of water they created. In consequence of this hunger drive and the general difficulty in maintaining a respiratory current in the diffuse shelter, the



EXPLANATION OF PLATE

1, Herbivors and scavengers with movable cases. 2, Carnivors building either fixed shelters or none at all. 3, Short cases. 4, Long case coiled in a flat spiral. 5, Fixed silken tubes, often with funnel mouths. 6, Fixed nets and snares. 7, Free-living larvae, never building more than loose silken wefts until preparing to pupate. 8, Case-building in later larval life but prior to preparations for pupation. 9, Lepidopterous stem. A. Ocelli absent. P. Ocelli present. U. Ocelli usually present (absent in some Hydroptilidae). The barrier separating "Ponds and slow streams" from "Fast streams" is largely one of dislodgement or displacement pressure. The separation of "Integripalpia" from "Annulipalpia" on the basis of secondary segmentation of the maxillary palpi seems to have no phylogenetic basis. An angulate trench indicates the limits of Martynov's suborders. The "Inaequipalpia" of Kolenati are distinct in that the adult maxillary palpi have less segments in the male than in the female, while all other Trichoptera show equal palpi in both sexes and are hence "Aequipalpia." A Z-shaped ditch separates the suborders of Kolenati.

larvae reacted in three different ways. The rhyacophilid stem left the shelters and actively hunted their animal prey, depending on the current of streams to bring their respiratory water. The other carnivors also moved upstream, but made their shelters in the form of loose structures on rock surfaces, using the water current to bring them more food, developing in some groups the instinct to weave nets and snares to increase the catch. The third group, the vegetarians and scavengers, reinforced the walls of the gallery, shortened it, separated it from the substratum and dragged it around in the ponds in search of more to eat. For protection or some other reason they became hypognathus (eruciform). Later a few from the various families in this group moved into fast water and now build satisfactory cases there and keep them from washing down stream, but are otherwise poorly adapted to their environment. The plate shows that differentiation according to the lines suggested above separates the subfamilies of Trichoptera into the groupings most apparent to modern systematists.

The test of any hypothesis is time and continued comparison with the observed facts. At present, this ecological explanation of the evolution of caddis worm case construction fits well with the data at hand. It is presumably to factors with a direct physiological bearing that biologists should look for causes of evolution, since the physiological features may also cause the morphology to be what it is.

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FIELD BOOK OF ANIMALS IN WINTER, by ANN HAVEN MORGAN. Pages xiv and 527; 257 text figs. and 26 pls. 4.25 x 7 inches. 1939. Published by G. P. PUTNAM'S SONS, 2 West 45th St., New York City. Price, $3.50.

This volume is one of the Putnam "Nature Field Books." It is the second in that series by Professor Morgan. Her first was the very useful "Field Book of Ponds and Streams" which appeared in 1930. The present volume is a pocket hand book of winter natural history. It is a guide to the animals more easily found in our woods, fields and waters during the colder months of the year and is for those real out-of-doors enthusiasts who have to ramble in winter as well as in summer. It appears to us as an excellent antidote for an over-dose of test tubes, adding machines and other laboratory equipment of indoor biology. We know of no other book which fills this gap in winter field excursions as neatly as does the Field Book of Animals in Winter.

In twenty-five well illustrated chapters are reviewed the common animal forms of the eastern States. With each chapter is a short bibliography of the more important items of literature on the particular group. Some chapter headings and subheads will indicate the nature of the work. Chapter 3. Seasonal Migrations: general downward migration; ground cover; migration from land to water, from shallow to deeper water; migration to distant regions. Chapter 4. Hibernation. Chapter 5. Winter Communities of Land Animals. Chapter 6. Seasonal Changes in Fresh Water and in Fresh-Water Animals. Chapters 7 to 25 discuss the winter habits of animals group by group from sponges to mammals.

One hundred twenty-five pages are given to insects in winter. They are covered in Chapters 15 to 18. As the matter on insects is about one-fourth of the book the information conveyed is extensive as well as interesting. In discussing seasonal adjustments Professor Morgan relates active periods to food supplies rather than the opposite, that of relating pupal stages and such to cold weather. Our present knowledge of insect adjustment to temperatures is so scanty that summer-winter cycles are still full of many puzzling adjustments. Why can a winter stonefly operate successfully on snow while many wasps can get about comfortably only in the hottest part of a summer day? We hope that this work will encourage physiologists to dip into the many such problems outlined.

As has already been suggested, this volume fills a gap in American natural history. Until we read the book we had not realized how wide the gap had been. At present field work almost ceases from the first fall frost to the opening of the first buds in spring. Now we have a guide for others than bird scouts.—C. H. K.

A REVIEW OF THE NEARCTIC BERIDINAE

(Diptera, Stratiomyidae)

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This paper is presented in the hope that it may serve to identify Nearctic specimens belonging to this subfamily of Stratiomyidae. It is complete, so far as our knowledge goes, for the Nearctic region, including all the United States, unless some Neotropical species may extend into our Southwest. In preparing it, I have examined specimens of all species, including the types that are to be found in American Museums, with the exception of *Beris canadensis* (Cresson).

The subfamily Beridinae is a primitive one, of world-wide distribution. It may readily be distinguished from the other subfamilies found in the Nearctic region by the seven-segmented abdomen; when seven segments are visible in other subfamilies, the terminal ones are telescoped into the fifth. *Hexodonta*, which in most keys will trace to the Clitellariinae, is placed here for reasons given in the discussion of that genus. It may readily be separated from the Clitellariinae by the possession in *Hexodonta* of six scutellar spines. The Neotropical Chiromyzinae, which also have seven abdominal segments, have rudimentary mouth parts, where as those of the Beridinae are well-developed. I agree with Dr. Curran in not including the Solvinae in the Stratiomyidae.

The antennae are of a simple type; they are ten-segmented, the last eight being fused into a flagellum which is variable in form, but never with a well defined style or arista. The multiplicity of scutellar spines, except in *Allognosta*, separates the Beridinae from our other Stratiomyidae, although some tropical members of other subfamilies may also have more than two spines.

Subfamily **BERIDINAE**

KEY TO GENERA

1. Scutellum unspined.....**Allognosta**
   Scutellum with four to six spines..... 2
2. Abdomen broad, seven-segmented, the sixth and seventh segments telescoped more or less into the fifth; media three-branched.....**Hexodonta**
   Abdomen slender, the seven segments distinct, the terminal ones not telescoped into the fifth; media two-branched..... 3
3. Eyes in the male contiguous; palpi small, knob-like, one-segmented; scutellum six-spined in the Nearctic species.....**Beris**
   Eyes separated in both sexes; palpi slender, three-segmented; scutellum four-spined.....**Actina**

Allognosta O. S.

Allognosta Loew, Berliner Ent. Zeit., 2: 297, 1883. (*n. n.* for *Metoponia* Loew, *nec* Macquart.)
Genotype, *A. fuscitarsis* (Say), by designation of Coquillett (1910).

Short, rather robust Beridinae with an unspined scutellum and well developed palpi. The genus is predominantly Holarctic, but several Oriental and two Neotropical species are known. The four Nearctic species may be separated by the following key:

KEY TO NEARCTIC SPECIES OF ALLOGNOSTA

1. Abdomen with the tergites more or less yellowish..... 2
   Abdomen uniformly black or bronze..... 3
2. Thorax and scutellum black; discal cell large and angular; knobs of the halteres dark brown at the base.....**fuscitarsis**
   Thorax and scutellum dark bluish green; discal cell small and less angular; halteres entirely yellow.....**similis**
3. Flagellum of the antennae long and cylindrical; pleura black....**obscuriventris**
   Flagellum of the antennae short and conical; pleura reddish.....**brevicornis**

Allognosta fuscitarsis (Say)

Beris fuscitarsis Say, Jour. Acad. Sci. Phil., 3: 29, 1823.

Black; the antennae, except apically, the proboscis, the legs in large part, the halteres, and the abdomen except laterally and apically, yellow; wings subhyaline; discal cell small. *Type*, Pennsylvania; lost. Common in New England and the Great Lakes region of the United States and Canada, southward to Pennsylvania, Kentucky and Arkansas, and westward to eastern Kansas, South Dakota and Minnesota.

Allognosta similis (Loew)

Metoponia similis Loew, Cent., IV, 44, 1863

Similar in appearance to *fuscitarsis*, but may be distinguished by the key characters. *Type*, New York; in the Museum of Comparative Zoology. My records are from New York.

Allognosta obscuriventris (Loew)

Metoponia obscuriventris Loew, Cent., IV, 45, 1863

A black species, with the basal three or four antennal segments, the proboscis, the legs in large part, and the halteres yellow to brownish yellow. The discal cell is smaller than in *A. fuscitarsis*, and the wings

are slightly more infuscated. *Type*, District of Columbia; in the Museum of Comparative Zoology. Common in New England and the Great Lakes region of the United States and Canada, southward to New Jersey, the Ohio River, and Missouri, and westward to eastern Kansas, South Dakota, and Minnesota.

Allognosta brevicornis Johnson

Allognosta brevicornis Johnson, Occ. Papers Boston Soc. N. H., 5: 71, 1923

Similar in appearance to *obscuriventris*, but readily distinguishable by the short, conical flagellum of the antennae and by the reddish pleura. *Type*, Vermont; in the Museum of Comparative Zoology. Recorded from Maine, New Hampshire, Vermont, Massachusetts, and New York.

Hexodonta Rondani

Exodontha Rondani, Dpt. Ital. Prodr. I, 169, 1, 1856
Scoliopelta Williston, Entom. Amer. 1: 119, 1885
Hexodonta Mik, Wien Ent. Zeitung, 16: 40, 1897
Genotype, *Hexodonta* (*Beris*) *dubia* (Zett.)

A genus of robust Beridinae; the eyes are densely pilose, contiguous in the male and separated in the female; the palpi are vestigial. Antennae with the first two segments subequal, the flagellum subconical. The wings are broad, the discal cell large and angular, the media with three strong branches. Scutellum six-spined. The abdomen is broader than the thorax, with seven segments, the apical two, however, rather small and often telescoped into the fifth. The genus is known from three species: *the genotype* (European), and the two American species discussed below.[1]

KEY TO THE SPECIES OF HEXODONTA

Third posterior vein (M_3) abbreviated, not approaching the wing margin; the first and second posterior veins leaving the discal cell at the same point; thorax and abdomen concolorous, black; legs in large part blackish..... **luteipes**
Third posterior vein reaching the wing margin; the first and second posterior veins separated at the apex of the discal cell; thorax and femora brownish; the abdomen black..... **grandis**

Hexodonta luteipes (Williston)

Scoliopelta luteipes Williston, Entom. Amer. 1: 119, 1885.

Type, from Vermont, in the Snow Collection, University of Kansas. Northeastern states; rather rare. I have records from New Hampshire, Vermont, Massachusetts, New York, and Tennessee.

Hexodonta grandis (James)

Scoliopelta grandis James, Pan Pac. Ent., 14: 156, 1938

Type, from Oregon, in the Oregon State College Collection. Known only from the type.

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[1]In a previous paper (James, 1938) I have considered the species of this genus, under the name *Scoliopelta*, as belonging to the *Clitellariinae*) however, the greater affinities with the Beridinae lead me to reverse my decision. The telescoping of the terminal abdominal segments, which seemed to ally this genus with the Clitellariinae, probably represents an independent development. The synonymy of *Scoliopelta* and *Hexodonta* was given by Enderlein (1921), though I reached the same conclusion independently.

Beris Latreille

Beris Latreille, Hist. Nat. Crust. et Ins., III, 447, 1802.
Genotype, *Beris* (*Musca*) *chalybeata* (Forster) (as *Stratiomys sexdentata* F., the only species).

A genus of slender, metallic green flies, with a more or less elongated abdomen. Antennae ten-segmented, the basal two segments subequal in length. Eyes pilose, contiguous in the male. Palpi small, one-segmented, more or less knob-like. Scutellum with four to six spines, always six in our species. Posterior basitarsi thickened and elongated. Species of *Beris* are found on every continent, though they do not seem to live under tropical conditions; the genus is best developed in the Palearctic Region. Four species have been reported from the Nearctic Region; they may be separated by the following key:

KEY TO THE NEARCTIC SPECIES OF BERIS

1. Head and thoracic dorsum clothed with bushy pile, which is predominantly black; thorax dark green, almost black ..... **californica**
   Head and thoracic dorsum clothed with relatively short, yellow pile; thorax bright green or bluish green 2
2. Mesonotum usually with four steel-blue vittae, otherwise brassy green; last male tergite truncate, with a straight spur on each side ..... **canadensis**
   Mesonotum wholly bright green; terminal male tergite not as described 3
3. Wings broad, brownish; male basitarsi but slightly enlarged; antennal flagellum greatly enlarged basally on the inner side, the enlargement more or less angular; terminal male tergite on each side with a spur which curves strongly under the cerci ..... **annulifera**
   Wings more slender, yellowish; male basitarsi greatly enlarged; antennal flagellum but slightly enlarged basally, the enlargement somewhat produced inwardly but not angular; terminal male tergite without lateral spurs ..... **morrisii**

Beris californica James, n. sp.

Male. Head shining black, clothed with bushy black pile which, near the antennae, is as long as the first antennal segment, and which becomes longer on the face; antennae black, the first and second segments with black hair; the flagellum at its base slightly thicker than the apex of the second segment, and gradually tapering to its apex. Eyes with dense black pile. Proboscis yellow, with yellow hair; palpi brown. Thorax metallic greenish black dorsally, the scutellum concolorous; the pile consists of bushy black hairs arising above a denser covering of semi-appressed yellow pile, which becomes more prominent anteriorly; pleura bluish-black, metallic. Scutellum with six metallic spines. Legs yellow; the fore and middle tarsi blackish from the middle of the first segment, the hind ones with the last three or four segments blackish; the posterior basitarsi longer than the remaining four segments combined and greatly thickened. Wings brownish-yellow, subhyaline, the veins but little darker than the membrane; stigma dark brown. Halteres brownish yellow. Abdomen dull black, subshining, clothed with black pile laterally; venter brownish or brownish yellow. Genitalia small; the last tergite truncate apically, not produced laterally into spines. Length, 7 mm.

Female unknown.

Holotype, male, Del Norte Co., Calif., May 27, 1910 (Oldenberg Coll.) In the collection of the Deutsche Entomologische Institut, Berlin-Dahlem.

Paratopotypes, 3 males, same data.

This species is related to the European *B. chalybea* Curtis; the face, however, is not so broad as in that species, though it is broader than in *B. annulifera*. My specimens of *chalybea* are blacker and have the head flatter above, with the line where the eyes join each other more deeply impressed.

Beris canadensis (Cresson)

Actina canadensis Cresson, Proc. Acad. Nat. Sci. Phil., 71: 174, 1919.

Head black, with short white pile; antennae black, the flagellum with its basal segment brownish; thorax green, more blackish on the pleura, and usually with four steel blue stripes on the dorsum; legs yellow; abdomen black; the terminal male tergite truncate, on each side prolonged into a spine which does not extend under the cerci. *Type*, female, Aweme, Manitoba, in the Philadelphia Academy of Science. Distribution, Manitoba and Alberta, Canada.

Beris annulifera (Bigot)

Oplacantha annulifera Bigot, Annales, 1887: 21, 1887.

Head black, with short white pile; antennae black, the flagellum somewhat brownish on the inner side; thorax bright green, more blackish on the pleura; legs yellow, but variably darkened or marked with black; abdomen black; the terminal male tergite truncate, produced laterally into two spines which curve inward under the cerci. *Type*, from Georgia, in the Bigot Collection. Distribution, Newfoundland to Hudson Bay, Alaska, California, Kansas, and Georgia.

Johnson (1926 b) has recognized three subspecies on the basis of the coloration of the legs. They are as follows:

Beris annulifera annulifera Bigot; legs yellow; hind femora with a more or less prominent subapical band of brownish black; tarsi black, with the base of the basitarsi yellowish. Widespread.

Beris annulifera luteipes Johnson: legs yellow, except the last four segments of each tarsus, and the apices of the front and middle basitarsi, which are black. *Type*, Seattle, Wash., in the Museum of Comparative Zoology. Widespread.

Beris annulifera brunnipes Johnson: legs dark brown, except the extreme bases of the femora and the basal third of the tibiae, which are yellow, and the tarsi, which are blackish brown. *Type*, Parroquet Island, Labrador, in the Museum of Comparative Zoology. Distribution, Labrador, Newfoundland, New Hampshire.

Beris morrisii Dale

Beris morrisii Dale, Entom., 175: 75, 1842.

This species probably does not occur in America, though it has been recorded by Loew (as *pallipes*), Van der Wulp, and Enderlein. As

Johnson (1926 b) points out, these authors have probably mistaken *Beris annulifera luteipes* for *morrisii*; and Johnson is quite correct in considering these two species distinct.

Actina Meigen

Actina Meigen, Klass., 1, 117, 1804.
Hemiberis Enderlein, Mitt. Zool. Mus. Berlin, 10: 209, 1921.
Allactina Curran, Canad. Ent., 56: 24, 1924.
Synonymy, Johannsen, Bul. Brooklyn Ent. Soc., 20: 24, 1924, and Johnson, Psyche, 33: 88–90, 1926.
Genotype, *Actina nitens* Latr., by designation of Rondani, 1864.

First antennal segment elongated, twice as long as the second, the flagellum eight-segmented, as long as the first and second combined. Eyes separated in both sexes. Scutellum four to six-spined. Male basitarsi more or less enlarged. Media two or three branched. The genus is represented by a number of species in the Palearctic and Australian regions, and by one each from Chile and from North America.

Actina viridis (Say)

Beris viridis Say, Longs Exped., App., 368, 1824.

Bright, metallic green, with black antennae, a yellow proboscis, predominantly yellow legs, and subhyaline wings; the scutellum is set with four yellow spines, and the media is two-branched.[2] *Type* from Pennsylvania; lost. Common in the Great Lakes region and the upper Atlantic seaboard; distribution, Newfoundland to South Dakota, Kansas, and North Carolina.

Johnson (1926 a) named a variety *obscuripes* on the basis of the coloration of the legs: in the male, the femora are brownish black, the tibiae yellow on only the extreme basal part and the tarsi are dark except the posterior basitarsi, which are brownish only apically; the female has the femora, except the tip, and the basal third of the tibiae yellow. Type, Anticosta Id., Newfoundland, in the Museum of Comparative Zoology.

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[2]The European *A. nitens* has a three-branched media, but in some specimens the third branch is greatly abbreviated, and in a few, according to Johnson (1926a) it may be absent. *A. viridis* seems normally to have the media two-branched; but the fact that Enderlein (1921) recorded both this species and *Hemiberis quadridentata* (= *viridis*) from specimens which he evidently had examined, may mean that an occasional *A. viridis* may have a three-branched media.

THE EGG CONTENT AND NYMPHAL PRODUCTION AND EMERGENCE IN OOTHECAE OF TWO INTRODUCED SPECIES OF ASIATIC MANTIDS

(Orthoptera: Mantidae)

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During the winter and spring of 1938 the writer kept under observation four lots of egg-masses, or oothecae, three belonging to a species of mantid, *Tenodera sinensis* Saussure, introduced into this country about 1896 from eastern Asia, the fourth to another species of Asiatic origin, *T. angustipennis* Saussure, first recorded in America from Delaware in 1933 (6)[1] and now known to occur abundantly also in southern New Jersey. The main object in view was to collect data of a quantitative nature on the biotic potentials (3) of these mantids which have increased enormously since their introduction. For this purpose data were recorded for each ootheca on (a) the number of eggs deposited, (b) the number of nymphs produced, and (c) the number of the latter which emerged as living young. By the biotic potential of a species the writer understands its innate capacity for reproduction and survival. As contributing to these ends must obviously be counted the factors mentioned.

Although both species are referred to the same genus, their oothecae, as Jones (6) has shown, are radically different. In *T. sinensis* it is a bulky, somewhat globular structure, a large part of which, as noted by Weiss (11), is formed by the thick outer covering, consisting of a tough, highly vesicular matrix, deep within which is embedded an inner, horny capsule containing the eggs. As a result, this capsule is far removed from the surface, except along the side where the ootheca is attached to a twig or other form of support. In *T. angustipennis*, however, the ootheca is constructed essentially like that of the native *Stagmomantis carolina* (Johannson), but averaging larger. It is of an elongate, roughly cylindrical form, with the attached side flattened or, more frequently, shallowly concave. Its external covering is quite thin and not very clearly separable from the

[1]Numbers in parentheses refer to Literature cited.

wall of the inner capsule, which is everywhere close to the surface except at the two ends, beyond which the outer covering is prolonged for some distance along the support. From these striking differences in the form and structure of the two types of ootheca, it seems probable that the eggs of *T. sinensis* are better protected than those of *T. angustipennis* against dangers arising from sudden or extreme changes in temperature and other physical agencies in the environment and from the attacks of predators and parasites.[2]

MATERIAL

Of the material used in these observations, two lots of oothecae of *T. sinensis* were from the Bronx section of New York City, especially the part adjoining Pelham Bay Park. The first, designated Lot A, consisted of fifty-five oothecae obtained early in December, 1937, the second, termed Lot B, of fifty-three oothecae collected in March, 1938, to determine the effect of exposure throughout the winter upon the proportion of eggs hatching.

A third set, composed of twenty-seven oothecae of *T. sinensis*, designated Lot C, was collected late in December, 1937, at Ocean View, Cape May County, New Jersey.

The entire series of seventy oothecae of *T. angustipennis*, forming Lot D, were also from Ocean View, where they were collected at the same time as the preceding.[3]

PROCEDURE

With the exceptions referred to in the next paragraph, the oothecae, when brought into the laboratory, were placed each in a separate glass jar, lightly covered with the lid, where it was retained at the normal temperature of the room until nymphal emergence was complete. The oothecae were then dissected under a binocular and examined for unhatched or undeveloped eggs and for any nymphs which had failed to emerge and had died in situ. In this way figures were obtained for each ootheca on the number of eggs originally present, the number of nymphs formed, and the number of the latter which actually emerged as active young.

In the case of *T. angustipennis* the procedure just described was strictly followed only in about twenty-five oothecae, the others being retained for some time in the same receptacle in which they had been transported to the laboratory. This change was rendered necessary by

[2]Caudell (2) in 1928 recorded as a variation in *T. sinensis* the deposition of elongate egg-masses, which, from his description, are obviously those of *T. angustipennis*, at that time not reported in this country. He casually records the finding of similar egg-masses outdoors in Washington, D. C., thus indicating the existence of the species in that city at least five years previous to the earliest published record (6) of its presence in this country.

[3]This species, although common in southern New Jersey, has apparently not yet spread to New York City.

the lack of a sufficient number of jars to accommodate the entire series. In the expectation that enough of the oothecae of Lot A would hatch to liberate the required jars before hatching began in the *T. angustipennis* series, the receptacle containing the excess oothecae was at first kept with the jars, the oothecae in both thus being exposed to essentially the same temperature conditions. However, hatching started when only about thirty-five of the oothecae of *T. angustipennis* were contained in separate jars, and, to retard it in the others, the box containing them was removed to a window-sill, where the lower temperature would serve this purpose. As will be shown later, this treatment evidently had a highly detrimental effect upon the developing nymphs, which doubtless had already reached a stage when they were nearly ready to hatch. Such injury was unexpected, since the writer had earlier observed similar advanced nymphs in a few oothecae collected outdoors in midwinter and, on this basis, had thought it unlikely that moderate chilling at the same stage would have injurious effects.

TABLE I

NUMBER OF EGGS IN OOTHECAE OF *Tenodera*

1937

Lot	Source	Number of Oothecae	Total	Number of Eggs		
				Mean	Minimum	Maximum
			T. sinensis			
A	Bronx.....	55	14,367	261.2 ± 5.30	0	365
"	"	54	14,367	266.1 ± 4.30	126	365
"	"	51	13,733	269.3 ± 4.18	140	365
B	"	53	14,059	265.3 ± 3.81	166	379
"	"	48	12,936	269.5 ± 3.73	186	379
C	Ocean View...	27	7,731	286.3 ± 4.45	230	351
			T. angustipennis			
D	Ocean View...	69	16,106	233.5 ± 3.34	93	335

OBSERVATIONS

Number of Eggs. Records of the number of eggs originally present in the oothecae of the four lots examined are summarized in Table I.

Listing of more than a single row of figures in Table I opposite each of the two Bronx lots of oothecae was dictated by the presence of several clearly abnormal examples in the material from that locality. In Lot A three oothecae showed no trace of the inner capsule, which in normal examples contains the eggs. In one eggs were absent, while in the other two they were present, but scattered promiscuously through a structureless matrix similar to and continuous with that which in normal oothecae forms the outer covering. In such cases the cells containing the eggs, excepting a few subjacent to the surface, have no openings to the exterior and hence any nymphs hatching in them perish in situ. A fourth ootheca in Lot A was not obviously abnormal in structure, but most of the eggs showed no trace of development, forming when exam-

ined hard, dry bodies of a reddish-brown tint lying loose in their cells. Such eggs had probably not been fertilized.

In Lot B five oothecae were abnormal, one lacking an inner capsule, with the eggs distributed irregular through the matrix, the others apparently normal, but containing only, or a very high proportion of, undeveloped and presumably unfertilized eggs.[4]

From the preceding account, it is clear that where, as in Table I, more than a single row of figures is listed opposite a stated lot of oothecae, those of the last row pertain to normal material. However, it was deemed advisable to also list the values obtained when the abnormal examples are included. Abnormality is as much a natural phenomenon as is conformity to type and obviously needs to be taken into account in forming an idea of the population likely to emerge from a series of oothecae collected outdoors at random. Likewise, it is equally desirable to have available, for purposes of comparison, an index of the population likely to emerge from oothecae all normal in structure and in the capacity of their eggs to develop.

In the series of *T. angustipennis*, forming Lot D of Table I, seventy oothecae were originally included, but one was examined and destroyed previous to hatching. Inclusion of the number of eggs originally present in this ootheca yields an average (233.4 ± 3.29) practically identical with that based upon the remaining oothecae of the same series.

Table I shows the average number of eggs as essentially identical in the oothecae of both lots of *T. sinensis* from The Bronx. In the series of the same species from Ocean View it is indicated as considerably greater. The question arises whether this difference in the material from the two localities is statistically significant. The wide range of variation shown, as also the fact that the extremes (230–351) in the Ocean View lot fall well within the limits of range in either of the Bronx lots, suggests that the difference is not significant. This view is substantiated by the fact that the difference is slightly less than three times its probable error if comparison is limited to the highest averages (269.3 and 269.5) listed for the Bronx lots. However, when lower values (e. g., 266.1 and 265.3) for the latter are used for comparisons, the difference slightly exceeds three times its probable error, even when allowance is made for the small size of the sample in the group from Ocean View. The weight of evidence seems to favor the negative view, but the question, in the opinion of the writer, can be definitely solved only in the light of further data.

The number of eggs in oothecae of *T. angustipennis* is definitely indicated as less than in those of the older established species, although the differences in the averages (31–52) are not impressive. Computation, however, shows that they are statistically significant.

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[4]It is interesting to find Rau and Rau (8) recording the construction of apparently normal oothecae by virgin females of *Stagmomantis carolina*. Oothecae so produced yielded no young. The above-mentioned cases in *Tenodera* are probably not quite comparable, since from two of the oothecae a small number of young emerged. This suggests their construction by mated females under circumstances permitting fertilization of only a limited proportion of the eggs. Possibly the low temperatures prevalent late in the autumn, when construction of oothecae is still in progress, may more or less inhibit the motility of the sperm, or perhaps interfere with their release from the spermatheca, thereby ensuring fertilization of, at most, only a small number of the eggs being deposited.

The frequency distribution of the variations in the egg content of the oothecae studied is summarized in Table II.

TABLE II

FREQUENCY DISTRIBUTION OF VARIATIONS IN EGG CONTENT OF OOTHECAE OF *Tenodera*

NUMBER OF EGGS PER OOTHECA	NUMBER OF OOTHECAE			
	T. sinensis			*T. angustipennis*
	Bronx (A)	Bronx (B)	Ocean View	
0	1	0	0	0
75– 99	0	0	0	1
100–124	0	0	0	0
125–149	2	0	0	1
150–174	1	1	0	1
175–199	1	2	0	11
200–224	3	7	0	11
225–249	13	4	4	22
250–274	11	14	7	12
275–299	10	16	6	8
300–324	9	6	6	2
325–349	3	2	3	1
350–374	1	0	1	0
375–399	0	1	0	0
Total	55	53	27	70

TABLE III

CORRELATION BETWEEN SIZE OF OOTHECA AND NUMBER OF EGGS IN *Tenodera*

Length of Ootheca	*T. sinensis*						*T. angustipennis*		
	BRONX (A)			OCEAN VIEW (C)			OCEAN VIEW (D)		
	Number of Oothecae	Eggs per Ootheca		Number of Oothecae	Eggs per Ootheca		Number of Oothecae	Eggs per Ootheca	
		Mean	Range		Mean	Range		Mean	Range
16–17 mm.	1	140	.....	0	.....	.....	1	93	.....
18–19 "	0	.....	.....	0	.....	.....	1	130	.....
20–21 "	3	223	167–279	0	.....	.....	2	181	169–193
22–23 "	8	243	195–273	1	265	.....	2	182	179–185
24–25 "	10	246	206–290	5	275	246–318	16	214	177–266
26–27 "	7	253	226–288	6	269	230–307	10	229	186–278
28–29 "	8	302	264–341	8	289	235–345	11	239	206–277
30–31 "	9	294	266–325	5	302	254–351	15	257	217–295
32–33 "	3	302	270–365	1	310	.....	5	303	257–335
34–35 "	4	321	303–348	1	342	.....	3	261	238–277
36–37 "	0	.....	.....	0	.....	.....	1	244	.....
38–39 "	0	.....	.....	0	.....	.....	0	.....	.....
40–41 "	0	.....	.....	0	.....	.....	1	234	.....
Total....	53	.....	.....	27	.....	.....	68	.....	.....

In Table III is shown the observed correlation between the size of the ootheca, as indicated by its length, and the number of eggs present.

No measurements were made of the oothecae in Lot B, hence this lot is not included in the table.

In all cases measurements were made of the length of the entire ootheca. Probably a better correlation between length and egg content would be obtained by cutting away the outer envelope and measuring the inner capsule. In *T. angustipennis* especially it is frequently difficult to decide between what points to measure the length, as the frothy covering at one end of the ootheca tapers off for a variable distance beyond the end of the inner capsule.

NYMPHAL PRODUCTION AND EMERGENCE

Records of the number of nymphs produced in the oothecae and of those which emerged as living young yielded the results summarized in Table IV.

TABLE IV

NYMPHAL PRODUCTION AND EMERGENCE IN OOTHECAE OF *Tenodera*

Lot*	Number of Oothecae	Number of Nymphs							
		Produced				Emerging			
		Total	Mean	Minimum	Maximum	Total	Mean	Minimum	Maximum
				T. sinensis					
A	54	13,140	243.3±6.36	6	361	12,668	234.6±6.96	0	356
"	51	12,989	254.7±4.81	136	361	12,660	248.2±5.01	134	356
B	53	11,791	222.5±7.10	0	322	11,323	213.6±7.17	0	317
"	48	11,735	244.5±3.74	156	322	11,313	235.7±3.96	147	317
C	27	7,484	277.2±4.73	223	347	7,302	270.4±5.22	198	340
				T. angustipennis					
D	69	15,258	221.1±3.92	70	330	12,172	176.4±5.95	10	300

*See Table I.

Nymphal production and emergence are summarized separately in Table IV, since some of the nymphs formed failed to hatch, while others died before reaching the exterior. Hence, in every lot of oothecae the total number of nymphs emerging was considerably less than the number produced. However, in nine oothecae of *T. sinensis* and one of *T. angustipennis* the two were equal, emergence, therefore, being 100 per cent. Of the remaining oothecae, one hundred of the former and seventeen of the latter gave emergences in excess of 95 per cent. If clearly abnormal cases be disregarded, the lowest emergences observed in oothecae of *T. sinensis* were 76.2 per cent in one from Ocean View and 76.4 per cent in another from New York. In this species only ten oothecae gave emergences of less than 90 per cent.

In *T. angustipennis* the proportion of emerging nymphs exhibited a wide range, the minimum being as low as 5 per cent, while as many as

thirty-five oothecae gave emergences of less than 90 per cent. The results obtained in this instance are doubtless not representative of the species, the probable cause of the abnormality, as earlier stated, being the exposure of most of the oothecae to low temperatures at a critical stage in nymphal development. If the oothecae of this species be grouped, according to sequence of emergence, into three sets of twenty-three each, the following suggestive results are obtained. In the first set, which was largely composed of oothecae kept uninterruptedly under temperatures favorable for hatching from the beginning of the experiment, seventeen gave emergences above 90 per cent, while in the second group ten and in the third only five oothecae gave comparable results. It is, therefore, probable that under identical conditions the proportion of nymphs emerging in *T. angustipennis* would closely approach that observed in *T. sinensis*.

The differences in averages given in Table IV for both nymphal production and emergence within the Bronx series of oothecae are shown by computation to lack statistical significance. Hence, the reduction in both categories empirically indicated in Lot B, which consisted of oothecae exposed outdoors during the winter, cannot be regarded as fully proved. However, the differences in averages between the Bronx series and the lot of *T. sinensis* from Ocean View may be significant, since the differences, even when comparison is made with the highest averages (254.7 and 248.2) listed for the former, slightly exceed three times their probable errors. But the excess is so small, varying from a half to less than three units, that acceptance of such an indication as final would be unwarranted.

Comparison of the total number of nymphs produced with the number of eggs originally present (Table I) shows that, in cases where only normal oothecae were involved, the proportion of eggs giving rise to nymphs ranged in the different lots of *T. sinensis* from 90.8 per cent to 96.8 per cent, with a weighted average for all three lots of this species of 93.6 per cent. In *T. angustipennis* 94.7 per cent of the eggs produced nymphs, a result which favors the previously expressed view that normal emergence in this species is likely to be proportionately as high as in *T. sinensis*.

Individual records show between 90 and 100 per cent of the eggs giving rise to emerging young in 88 out of a total of 126 normal oothecae of *T. sinensis* and in 26 out of a total of 69 of *T. angustipennis*. In the latter the reduced emergence, as previously indicated, was abnormal and, hence, calls for no further consideration in estimating the proportion of eggs likely to produce active young. In *T. sinensis*, at least, the normal condition is indicated as that where more than 90 per cent of the eggs in the ootheca develop into emerging young, and this will probably also be found true of the other species. Deviations from this rule are attributable to special conditions, among which may be mentioned the defective structure of the ootheca, the incomplete fertilization of the eggs, and a high mortality in developing nymphs. The last-mentioned cause is probably important as a reducing factor only under exceptional circumstances, as evidenced in the rarity of any considerable loss from nymphal mortality in all oothecae except those which were

either structurally defective or had been exposed to temperatures detrimental for normal development.

A slight reduction in nymphal production and emergence was caused by parasitism in *T. angustipennis*. In *T. sinensis* reduction from this cause was negligible. The subject of the parasitic infestation of the oothecae of these mantids, along with the resulting nymphal mortality, is reserved for special treatment in a separate paper.

DIURNAL PERIODICITY IN EMERGENCE

Rau and Rau (8) in commenting upon emergence as observed in *Stagmomantis carolina*, state that "almost without exception the insects left the ootheca during the early morning. In many instances 6 A. M. found them already emerged, and very seldom did they leave after 8:30 A. M. . . . Some egg-cases bring forth all their young simultaneously and others on two, three or four mornings."

In essential respects the experience of the present writer with emergence in both species of *Tenodera* parallels the observations of the authors mentioned on *Stagmomantis*. The main difference is that emergence in general occurred throughout the entire morning, although becoming infrequent after 11 A. M. and quite exceptional after the noon hour. The precise time at which it began was not determined, but some emergence had already occurred by 7:30 A. M. Although no systematic records were kept, the general impression of both the writer and Dr. Ludwig, who was frequently present when the writer's duties called him elsewhere, was that emergence occurred most frequently between 8:30 and 10:30 A. M.

Emergence, as in *Stagmomantis*, was frequently essentially simultaneous, practically all the nymphs leaving the ootheca within less than an hour. In most instances, however, a limited proportion emerged from two to three days after the first emergence and in some cases a few as much as a week later.

DISCUSSION

The writer has found in the literature only a few references to the egg or nymphal production of *Tenodera* and these were limited to the older established species, *T. sinensis*, which until recently was referred by authors to *Paratanodera* Rehn, a genus now recognized as inseparable from *Tenodera* Burmeister (5). Laurent (7) in 1913 kept egg-masses of this species to see how many would emerge from each, the result being 150 from the smallest and 300 from the largest, a range of variation which falls well within the apparently normal limits (134 to 356) observed by the present writer. Weiss (11) in 1914, describing the "egg-nest" of the same species, records the core (inner capsule) as composed of twelve to eighteen layers, with an average of 15 eggs to a layer. This implies an average of somewhere between 180 and 270, approximately 225, eggs per ootheca, which is less than that found in the present writer's series, where the average (269) in the New York lots, almost coincides with the maximum computable from the results reported by Weiss.

Bromley (1) in 1932 reported that approximately 75 mantids hatched from each of 11 egg masses of *T. sinensis* received in March, 1930, from William T. Davis. Judging from the results reported in this paper, this is a very low figure. Since the material had probably passed the winter outdoors, the low emergence reported may be plausibly attributed to heavy winter mortality. The results obtained by the present writer with overwintering oothecae (Bronx Lot B), however, fail to substantiate such a view, the emergence being so little less than in other material collected before the winter was far advanced, that no statistical significance can be attached to the difference. However, it is at least possible that the winter of 1929–'30, to which Bromley's material was exposed, may have been more detrimental to the oothecae than was the rather mild winter of 1937–'38. On the other hand, it is possible that some unrecorded incident, analogous to that presumably responsible for the reduced emergence shown in the present writer's series of *T. angustipennis*, may have been responsible for Bromley's exceptional results.

Comparison with the larger of our native mantids, as exemplified in the genus *Stagmomantis*, shows a decided superiority in the introduced oriental types as regards egg production and nymphal emergence. According to Rau and Rau (8), 39 egg-cases of *S. carolina* (Johannson) yielded a total of 2,265 nymphs, the number emerging in the separate oothecae varying from 0 to 140. The observed average in this instance was 58, but, if only the 21 perfectly sound and normal egg-cases be considered, the minimum was 36 and the average 91. These figures were for the emerging nymphs and not for the eggs. An idea of the number of the latter is obtainable from Girault's records (4) of eggs in 20 egg-cases of the same species from Myrtle, Georgia, collected in November, 1906. These showed a range of 49 to 115 in single oothecae, with an average of 88.6. This result, compared with the average emergence given by Rau and Rau, points to an emergence in this species fully as high relatively as in *Tenodera*, but obviously with a much lower absolute number of nymphs coming out of the ootheca.

In the southwestern *Stagmomantis limbata* Hahn, as reported by Roberts (9), 7 egg-masses collected in the field gave rise to 454 emerging nymphs, an average of 65, with a maximum per egg-mass of 131. Twenty-seven other egg-masses deposited by females in captivity were shorter than those taken outdoors and yielded reduced numbers of nymphs, the average being about 46 and the maximum per egg-mass 79. Only the figures based upon field-collected material can be regarded as suitable for comparison with the results here reported for *Tenodera*.

It is evident, therefore, from, at least, the standpoint of eggs deposited and nymphs emerging from the ootheca that both introduced Asiatic mantids exhibit a biotic potential far superior to that found in any native species, for which comparable data have been reported. Whether this superior status would be as marked if the number of oothecae produced by each female be taken into account is a question to which no definite answer can be given, as no data on this point appear to have been published for either species of *Tenodera*. In *Stagmomantis carolina* Rau and Rau (8) reported that, so far as observed, no more than two egg-masses were produced by a single female, but in *S. limbata*,

according to Roberts (9), single females produced from three to six egg-masses, with an average of 179 nymphs per female and a maximum of 326. Since these numbers fall within the range of variation in nymphal production of single oothecae in either species of *Tenodera*, and since it is not likely that in the latter a female produces only a single ootheca,[5] little doubt can exist that, even from this wider point of view, the advantage rests with the two introduced species.

A third foreign species of mantid, *Mantis religiosa* Linnaeus, is known to be established locally in the northeastern United States, but is as yet unreported from the vicinity of New York City or from any point in New Jersey. Roeder (19), who has reared this species in this country, states that its egg-cases contain from 150 to 200 eggs. Its reproductive potential is thus also indicated as inferior to that of the two forms of *Tenodera*.

Although both species of *Tenodera* are potentially highly prolific, the older established form, *T. sinensis*, appears to have a slight advantage over *T. angustipennis*, at least as regards the number of eggs deposited in the ootheca and of nymphs which emerge. Whether this conclusion would be substantiated if other factors influencing survival—as, for example, susceptibility to disease, agility in capturing prey, general aggressiveness, likelihood of parasitic infestation, etc.—are given due weight is a question which can scarcely be answered in the light of the limited range of evidence presented in this paper.

SUMMARY

1. In two lots of oothecae of *T. sinensis* from the Bronx section of New York City, one of fifty-five examples collected in December, 1937, the other of fifty-three examples taken in the following March, the average number of eggs per ootheca was 261.2 ± 5.3 in the former and 265.3 ± 3.8 in the latter. Limitation of the counts to apparently normal material, fifty-one oothecae in one, forty-eight in the other, yielded essentially identical averages, namely, 269.3 ± 4.2 and 269.5 ± 3.7.

2. In twenty-seven oothecae of *T. sinensis* from Ocean View, New Jersey, the average number of eggs per ootheca was 286.3 ± 4.45. The difference between this average and those of the same species from the Bronx is apparently not statistically significant.

[5] In 1927 Mr. Charles H. Ballou, then a colleague of the writer at the old Japanese Beetle Laboratory at Riverton, New Jersey, made some unpublished observations on production of oothecae in *T. sinensis*. In answer to the writer's inquiry, Mr. Ballou (*in litt*) states that he does not recall how many mantids were kept under observation, but that three of the females each produced more than a single egg-mass. The second egg-mass was begun like the first, but was somewhat shorter and more concave below. One female produced a third egg-mass consisting of a mere cap, convex above, concave below, in which Mr. Ballou does not recall if eggs were present. These egg-masses were constructed by mantids collected as adults outdoors and, hence, the possibility is not precluded that they may have deposited other egg-masses before being placed under observation.

3. In seventy oothecae of *T. angustipennis* from Ocean View the average number of eggs per ootheca was 233.4 ±3.3.

4. The minimum number of eggs in single oothecae of *T. sinensis* from the Bronx was 0, but, if one ootheca be discarded, 126 and, if restricted to normal cases, 140. In oothecae of the same species from Ocean View the minimum was 230, while in those of *T. angustipennis* from the same locality, it was 93.

5. The maximum number of eggs per ootheca in material of *T. sinensis* from the Bronx was 379, from Ocean View 351. In *T. angustipennis* it was 335.

6. Obviously abnormal oothecae were restricted to the material of *T. sinensis* from the Bronx. The abnormality in such cases was structural and consisted in the absence of the inner capsule which in normal cases contains the eggs. Such structurally defective oothecae usually contained eggs irregularly distributed through the matrix, but one case was found where eggs were absent.

7. Oothecae, not structurally defective, are occasionally abnormal in containing eggs, all, or a high proportion, of which fail to develop, presumably because unfertilized. Several examples of such oothecae were found in material of *T. sinensis* from the Bronx and one in that of *T. angustipennis* from Ocean View.

8. A distinction is drawn between the number of nymphs produced in the ootheca and the number which actually emerge from the latter as living young. Some of the nymphs formed die while inside the egg or, if they hatch, before reaching the surface of the ootheca.

9. In normal oothecae the proportions of eggs which developed into nymphs was high, averaging 93.6 per cent in *T. sinensis* and 95 per cent in *T. angustipennis*.

10. Normally the porportion of nymphs emerging as active young is also indicated as high, usually in oothecae of *T. sinensis* exceeding 95 per cent. In *T. angustipennis* the emergence obtained was much less, but this result was probably abnormal, due to the temporary exposure of part of the material of that species to unfavorable conditions at an apparently critical stage in the development of the nymphs. Analysis of the data makes it seem probable that, under similar conditions, emergence in *T. angustipennis* would average nearly, if not quite, as high as in *T. sinensis*.

11. Comparison of two lots of oothecae from the Bronx, one collected before winter had far advanced, the other after it was past, indicates in the latter a possible slight reduction in the proportion of nymphs produced and emerging. The difference, however, is so small that it cannot be accepted as statistically significant. Possibly the relative mildness of the winter of 1937–'38 may have been responsible for the absence of any marked mortality.

12. Diurnal periodicity in emergence was observed in both species of *Tenodera*, closely paralleling that described by Rau and Rau in *Stagmomantis*, but differing in its duration throughout the entire forenoon, instead of terminating about 8:30 A. M.

13. From the point of view of potential survival as determined by egg production and nymphal emergence, both species of *Tenodera* are indicated as having a decided advantage over native forms of mantids, as exemplified in *Stagmomantis*. From the same standpoint, they are also indicated as superior to another introduced form, *Mantis religiosa*.

14. On the same basis, compared with each other, *T. sinensis* is indicated as having a slightly better chance of survival than *T. angustipennis*.

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INFESTATION OF OOTHECAE OF INTRODUCED ASIATIC MANTIDS BY PODAGRION MANTIS ASHMEAD

(Orthoptera: Mantidae; Hymenoptera: Chalcididae)

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Examination of two lots, one consisting of twenty-seven oothecae of the Chinese mantis, *Tenodera sinensis* Saussure, the other of seventy belonging to the more recent introduction, *T. angustipennis* Saussure, disclosed the presence in both forms, but especially the latter, of the egg-parasite, *Podagrion mantis* Ashmead.[1] Both lots were collected late in December, 1937, at Ocean View, Cape May County, New Jersey.

Only a single adult of *Podagrion mantis* was found in the entire lot of oothecae of *T. sinensis*. It had not emerged, but was exposed dead in one of the cells when the ootheca was dissected. This cell was located close to the margin of the area of attachment of the ootheca to the supporting twig, and, therefore, in a relatively superficial position. In this lot of oothecae a total of 7,731 eggs had been deposited. This gives a loss of 0.013 per cent from parasitism in this sample of *T. sinensis* from Ocean View. In the particular ootheca affected 299 eggs had been deposited, its infestation by the parasite thus being 0.344 per cent.

In the series of *T. angustipennis*, three oothecae were found infested. These yielded a total of 61 *Podagrion mantis*, many of which were adults, the others pupae and larvae. The total number of mantid eggs originally deposited in the entire lot of oothecae of this species examined was 16,342. Parasitism by the *Podagrion* thus amounted to 0.373 per cent, nearly thirty times that found in *T. sinensis*.

In the three parasitized oothecae of *T. angustipennis* the parasites obtained numbered respectively 17, 19 and 25. The corresponding number of mantid eggs originally present was 235, 189, and 236. Hence, the parasitism in the first ootheca

[1]The writer is indebted for the determination of the parasite to J. C. Crawford and A. B. Gahan, of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

was 7.23 per cent, in the second 10.05 per cent, and in the third 10.59 per cent. Of these parasites, 25 were found in an ootheca dissected before any parasites or mantids had emerged. Of the remaining 36 parasites, 14 emerged as living adults, the others being found dead in their cells on subsequent examination of the oothecae.

Podagrion mantis has been long known as an egg parasite of the native species of mantid, *Stagmomantis carolina* (Johannson). Girault (4)[2] in 1907 recorded ten oothecae of that species as producing 578 mantids, 240 *Podagrion* and 12 hyper-parasites, a loss from parasitism of 30.4 per cent. Apparently the oothecae were not examined in this instance for undeveloped eggs or for parasites failing to emerge; the percentage given, therefore, refers to emerging individuals and not to the original content of eggs of the oothecae, as here reported in the case of the two species of *Tenodera*.

Rau and Rau (5) in 1913 reported eight, out of a total of thirty-nine, oothecae of *S. carolina* as parasitized by *Podagrion mantis*. One ootheca was noted as entirely parasitized (presumably because no mantids, but only parasites, emerged), two others as heavily infested, while the numbers emerging in the remainder were given as 4, 11, 15, 25, and 60.

Podagrion mantis probably first spread to oothecae of the introduced *T. angustipennis* in some section of this country where the range of the latter overlaps that of *S. carolina*. This might be anywhere in southern Delaware, eastern Maryland, the District of Columbia[3] or extreme northern Virginia. Both species construct essentially similar oothecae, with the outer covering quite thin and, therefore, easily penetrable by the ovipositor of the parasite.

The limited degree of parasitism here reported for oothecae of *T. angustipennis*, as compared with its indicated frequence in *S. carolina*, is attributable to the absence of the latter in southern New Jersey (2). *Podagrion mantis* has not been hitherto reported from that State and there can be little doubt that it is a recent invader, following in the wake of *T. angustipennis* as that mantid extended its range northward beyond the limits of distribution of the original host, *S. carolina*. The present scarcity of the parasite in Cape May County may, therefore, be corre-

[2]Numbers in parentheses refer to Literature Cited.

[3]In 1928 Caudell (1) recorded as a variation in *T. sinensis* the production of elongate oothecae by mantids collected in Washington, D. C., which from his description are clearly indicated as those of *T. angustipennis*.

lated with the relatively late date of its entry into the County, which was probably retarded all the more by the presence of Delaware Bay across its line of advance.

The almost complete freedom of oothecae of *T. sinensis* from parasitism by *Podagrion*, even in a district where, as at Ocean View, the latter is present, is doubtless due to the unusual thickness of the spongy outer covering of the ootheca of this species, which would make oviposition by the parasite difficult or impossible. It is only where the inner capsule, containing the eggs, lies close to the surface, as is the case along the margin of the area of attachment of the ootheca to its support, that the eggs could be readily reached by the ovipositor of the parasite. It was in precisely such a situation that the solitary *Podagrion mantis* found in an ootheca of this species of mantid was encountered.

No trace of parasitism was found in a series of 108 oothecae of *T. sinensis* collected between December 1, 1937, and March 25, 1938, in the Bronx section of New York City. The reason in this instance is the local absence of *Podagrion mantis*, as well as of its more usual host, *I. angustipennis*, neither having as yet extended its range as far north as that city.

From the standpoint of susceptibility to attack by *Podagrion mantis*, as exemplified in the limited amount of data here presented, the biotic potential of the more recently introduced mantid, *T. angustipennis*, is definitely indicated as inferior to that of the older established form, *T. sinensis*. This conclusion agrees with that previously reached in a study of the comparative number of eggs laid and young hatching in the oothecae of the two species (3). However, recent field observations in Cape May County, New Jersey, tend to show that *T. angustipennis* is more than holding its own in competition with its apparently more favored relative, thus indicating that other factors than those so far considered may perhaps be of greater importance in determining the relative number of survivors in the two species.

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TIME REQUIRED FOR THE DEVELOPMENT OF TRIBOLIUM EGGS AT 27° C.

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In connection with certain problems dealing with the growth of populations of the flour beetle, *Tribolium confusum* Duv. the writer wished to obtain an accurate mean value for the time required for the development of eggs from laying to hatching at 27° C., and 75% Relative Humidity. A value of 6.04 days (144.96 hrs.) has been published by Chapman and Baird (1), but as an extensive knowledge of the form of the frequency distribution of times contributing to this mean was also needed, it was decided to re-determine the value by means of an apparatus devised by the writer (to be described below), whereby larger numbers of eggs could be tested than in the case of Chapman and Baird's determination. A total of 624 eggs was used, of which 531, or 85.09% hatched.

As in Chapman and Baird's work, the eggs were obtained by sifting an initially egg-free culture at the end of one hour, the eggs thus being all of the same age within an hour. These eggs were then timed as regards development by means of the apparatus described below and shown in Fig. 1.

THE TIMING APPARATUS

The apparatus consists of a heavy hard-wood base, at one end of which a modified electric clock is fastened. A small cylindrical drum with a spiral groove in its periphery is attached to the hour-shaft of the clock, and a thin linen cord (sewing thread) passes from a pin set at one end of this groove, through two screw-eyes, to fasten finally to a small sledge which slides along in a pair of parallel vee-grooves milled in the base. Thus as the hour-shaft rotates, the thread is wound up in the groove and the sledge is towed along at a slow constant rate (about .75 cm. per hour). Its position at any time is determinable by reference to the time scale shown on the side of the base.

An ordinary microscope slide is held in the clamp shown at the top of the sledge, and the eggs under test are cemented to the outward face of this slide by means of minute drops of distilled water. The drop used for each egg must be very small,

lest the egg be flooded (this seems to interfere with hatching, possibly by hardening the shell). The remarkably tight sticking is made possible by reason of the thin coating of flour which normally adheres to *Tribolium* eggs, and provides a ready made harmless adhesive.

When an egg hatches, the larva extrudes itself from the shell and, unable to cling to the smooth glass, falls down onto a horizontal glass plate placed in a depression in the base beneath the sledge. As this plate is smeared with a film of vaseline, each larva is held at the point of impact, and by reference to the time scale, its moment of hatching is at once determinable.

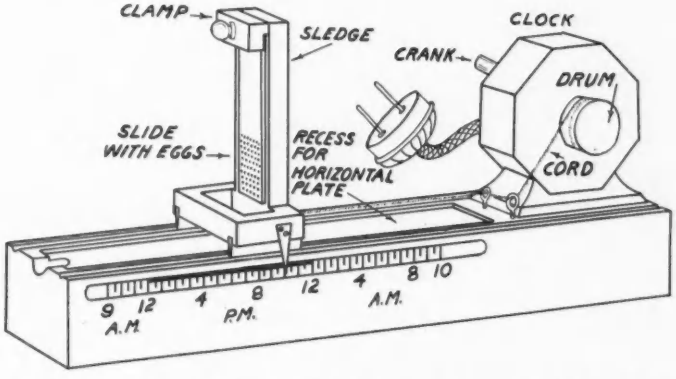

Fig. 1. Apparatus for determining the time required for the development of insect eggs.

It will be noted that the time scale is only long enough for a 24-hour run plus one hour's leeway. The sledge was therefore re-started each morning, with a new vaselined plate beneath it. A further safeguard is provided by the fact that the spiral groove runs off the end of the drum when the sledge has traveled for 28 hrs. The thread thus slips off the drum at this point, and the movement of the sledge ceases. As a matter of convenience, a crank is fitted to the time-adjusting shaft of the clock so that it can be turned in reverse to adjust the position of the sledge on starting a run. Incidentally, it was found by trial that knife-edged wooden runners (lignum vitae) produced a smoother motion of the sledge than any combination of wheels, ball-bearing or plain. The runners also obviate the necessity of precise levelling of the machine.

THE DATA

The pooled data from 12 runs are shown in Table I, and are plotted together with a smoothed frequency distribution in Fig. 2. This smoothed curve was obtained by the method of cumulative frequencies (Yule, (3)). A statistical analysis of the data of Table I is shown in Table II, from which it will be

TABLE I

RAW AND SMOOTHED DATA FOR THE DISTRIBUTION OF TIMES REQUIRED FOR THE HATCHING OF 531 EGGS OF *Tribolium confusum* AT 27° C., AND 75 PER CENT RELATIVE HUMIDITY

Time Required, Hours	Raw Frequencies	Smoothed Frequencies	Time Required, Hours	Raw Frequencies	Smoothed Frequencies
138	1	0.00	153	24	23.50
139	0	.25	154	22	18.50
140	1	1.25	155	14	14.50
141	3	4.00	156	13	11.25
142	7	9.75	157	6	8.50
143	16	19.75	158	5	6.50
144	32	33.50	159	5	5.00
145	55	44.00	160	5	4.00
146	47	49.00	161	1	3.00
147	54	51.00	162	3	2.50
148	44	50.50	163	2	2.00
149	54	47.75	164	2	1.50
150	40	43.00	165	2	1.00
151	46	36.50	166	2	.50
152	24	29.50	167	1	0.00

TABLE II

STATISTICAL ANALYSIS OF THE RAW DATA OF TABLE I

Mean time required for hatching, hours	149.21
Mean time required for hatching, days	6.22
Standard deviation, hours	4.55
Ratio, Mean/S. D.	32.82
Coefficient of variability, per cent	3.05
Standard error, hours	.197

seen that the mean value of 149.21 hr. is of good statistical significance. One may perhaps be inclined to cavil at the use of normal frequency distribution formulae for the analysis of a skew curve, but there is not much choice in the matter owing to the dearth of similar methods for the analysis of skew curves.

In Table III the percentages of eggs hatching in each hour from the 138th to 167th inclusive are shown, as well as the

cumulative percentages of hatch up to the beginning of each of the hours in the above interval. These were computed from the smoothed curve of Fig. 2.

TABLE III

PERCENTAGES OF *Tribolium* EGGS HATCHING BETWEEN THE nth AND (n+1)st HOUR, AND CUMULATIVE PERCENTAGES HATCHING UP TO THE BEGINNING OF THE nth HOUR, AT 27° C., AND 75 PER CENT RELATIVE HUMIDITY

Hour, (n)	Hourly Percent Hatch	Cumulative Percent Hatch	Hour, (n)	Hourly Percent Hatch	Cumulative Percent Hatch
138	.034	.....	153	4.391	85.724
139	.102	.136	154	3.560	89.284
140	.254	.390	155	2.916	92.201
141	.831	1.221	156	2.136	94.337
142	1.695	2.916	157	1.594	95.931
143	3.967	6.834	158	1.187	97.118
144	6.561	13.445	159	.983	98.101
145	8.511	21.956	160	.644	98.745
146	9.783	31.739	161	.441	99.186
147	10.105	41.845	162	.305	99.491
148	9.732	51.775	163	.220	99.712
149	8.986	60.563	164	.136	99.847
150	8.138	68.701	165	.085	99.932
151	6.918	75.619	166	.051	99.983
152	5.714	81.332	167	.017	99.999

The discrepancy between the writer's present value of 149.21 and Chapman and Baird's (1) value of 144.96 is not easy to explain. It is considered unlikely that it is due to faulty setting of the temperature in the writer's laboratory, as this would

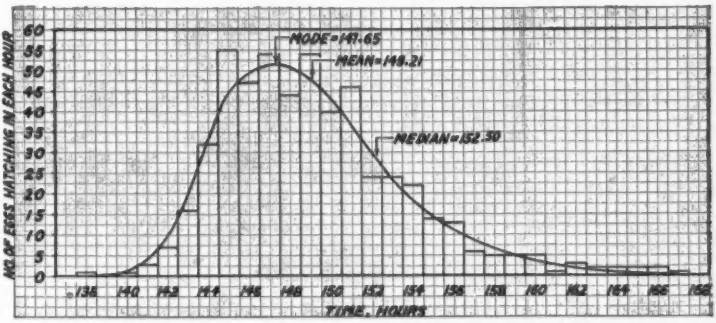

Fig. 2. Histogram and smoothed frequency distribution of the times required for the development of 531 eggs of *Tribolium confusum* at 27° C., and 75% Relative Humidity.

necessitate an error in setting of −.18° C. (approximately). This is a large error in view of the fact that tested thermometers were used, and that the accuracy of temperature control along the path traversed by the sledge was known to be ±.02° C. Further evidence against a faulty temperature setting is afforded by the fact that the means of the 12 runs did not differ from each other by as much as one hour, though the runs were done at times spaced as much as two months apart, and in some cases with different thermometers.

It might be suggested that sticking the eggs to the slide interferes in some way with hatching, and there may be some grounds for such a hypothesis, because definite flooding of the eggs does hinder hatching, and in any case, some larvae might try to escape from the egg by boring out on the side towards the glass, and then have to turn around and try at another point. However, after preliminary trials had pointed to the need of very small drops of water as adhesives, those used were as minute as it was possible to make them, and were barely large enough to dampen a small spot on the side of the egg towards the glass. The mortality for machine hatching is slightly higher (14.91% as against 11%) than hatching of eggs free in flour, but it is doubted if this difference is statistically significant.

Taking all things into consideration, particularly the ease and cheapness of the machine method as opposed to hourly visual observations, the writer prefers his own value, particularly as it is to be used in connection with the same machine for determining age frequency-distributions following Stanley (2).

SUMMARY

Data have been presented relative to the time required for the development from laying to hatching of the eggs of the flour beetle *Tribolium confusum* Duv. at 27° C., and 75% Relative Humidity, resulting in a mean value of 149.21 hours with a standard deviation of 4.55 hours. An apparatus is described whereby this time interval can be determined mechanically for large numbers of eggs.

ACKNOWLEDGMENT

The writer acknowledges with gratitude the financial support of the National Research Council of Canada and the Science Research Committee of Queen's University in connection with this work.

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The foregoing citation is so complicated that explanation may be desirable. Volume 6 is being issued in parts (*Lieferungen*) which do not correspond with the chief divisions of the table of contents. When completed, volume 6 will consist probably of five *Lieferungen* which are intended to be taken apart and bound in two volumes of convenient size. The division between these two "half volumes" occurs within the present *Lieferung*.

The second *Lieferung* was noticed in the March issue of the ANNALS to which reference should be made for the general character of this compilation on plant protection. A more extensive and critical review of the second *Lieferung* by Hubert Martin may be found in the Annals of Applied Biology 26: 196–197. 1939.

The present *Lieferung* contains in the first 70 pages by G. Hilgendorff and W. Fischer nearly all the section on chemical analysis of materials used for plant protection. The next 120 pages deal with biological control measures. Alvah Peterson looked over this section by Hans Sachtleben and was favorably impressed by it. The author reviews the outstanding work in the United States and elsewhere on the use of fungi, bacteria, and virus diseases for the control of insect and other pests. Control by vertebrates is briefly discussed. The use of insect predators is considered in more detail with a rather thorough review of the most recent work in this field. A discussion is given of the more recent outstanding examples throughout the world of biological control of important pests by native and introduced parasites. Numerous cross-references are given in the extensive bibliography.

The last part of this *Lieferung* is devoted to machinery for the application of insecticides and fungicides. Methods of making wet seed treatments are described by E. Riehm, dry treatments by A. Winkelmann. The final 48 pages by Hermann Zillig deal with spraying machinery and are illustrated by many cuts and photographs of sprayers and spraying operations. This section is largely limited to a description of German sprayers and spray application. Because of the cost of truck mounted high pressure sprayers and the smaller areas to be treated in Germany, hand operated sprayers and horse drawn equipment are much used. One will therefore not find descriptions or illustrations of recent American power sprayers, of stationary orchard equipment, of sprayers for the application of straight oil, or of airplane spraying, although some American practices are mentioned in the text. The references are mostly to the German literature. The scarcity of English citations is not altogether the fault of the author, because English publications on sprayers, outside of manufacturers' catalogues, are not numerous and no book on spraying and dusting equipment has appeared since that of Anderson and Roth in 1923. Technical study of design and performance of sprayers has lagged behind the study of insecticides, at least as far as publications are concerned, yet the efficient application of insecticides and fungicides is just as important as their composition. We do not feel that the present compilation by Dr. Zillig would be of much value to American entomologists, though the knowledge of German practices to be gained from it is instructive.

The index of volume 6 will appear in the final *Lieferung*.—F. L. C.

A PARTHENOGENETIC NEW SPECIES OF THE GENUS PERIMEGATOMA HORN

(Coleoptera: Dermestidae)[1]

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During the summer of 1938 Dr. H. H. Shepard of the Division of Entomology, University of Minnesota, brought to our attention a dermestid he had noticed in the laboratory in a nest of *Vespula arenaria* (Fabr.) (=*diabolica* Sauss.). Cultures were started and a series of adults obtained for study. This dermestid was previously represented in our collection by only a single specimen labeled "University Farm Campus, September 10, 1934." It proved to be undescribed in the literature relating to the North American fauna and in several respects it did not fit well into any described genus of the holarctic Dermestidae. The distinct characters which it shows might justify erecting a new genus for its reception, but until further revisional work is undertaken this seems undesirable. The closest affinities appear to be with species of *Perimegatoma* Horn.

Perimegatoma vespulae n. sp.

(Fig. 1)

Female. Body oblong, oval, slightly widened beyond the middle; pubescence inclined, prominent, shining, black throughout on dorsum, except an oblique, sinuate, luteus band on the basal half of each elytron not quite attaining the suture. Head almost invisible from above, covered with strongly inclined black pubescence, nearly one-half as wide as the greatest width of the thorax, with single, median ocellus and eyes prominently convex, entire; antennae pubescent, 11-segmented, scape and pedicel globular, flagellum gradually enlarging into a 4-segmented, slightly compressed, club, the segments subquadrate, except the last which is conical in outline and about twice as long as the third. Thorax convex especially at sides, sometimes showing weak depressions on dorsum, sides narrowly reflexed, surface shining, finely punctate, the greatest width nearly twice the length; scutellum small; elytra slightly wider than the thorax, broadly convex, with a transverse, depressed, basal area. Prosternum lobed in front, covering the mouth parts, except labrum and palpi, behind produced into a spine which fits into a well-defined groove along the entire length of mesosternum; mesosternum

[1]Paper No. 1710 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul.

emarginate behind at junction with the metasternum; antennal fossae absent; venter with fine recumbent golden pubescence; legs pubescent like venter, moderately stout especially the femora, hind coxae reaching beyond the middle of the meta-episternum, not contiguous, meta-basitarsus nearly equal to segments 2 and 3 combined.

Head and thorax usually entirely black as well as basal area of elytra, behind which is a testaceous, transverse, interrupted band bearing luteous pubescence, the remainder of elytra dark reddish brown, except black along the suture; antennae, except club which is black, testaceous with scape sometimes darker; legs testaceous, middle and hind coxae and femora, except apices usually appearing darker.

Length 3–4 mm.

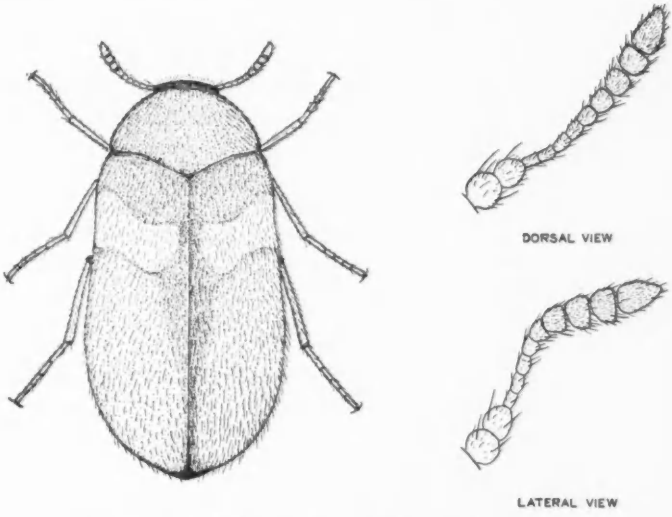

Fig. 1. *Perimegatoma vespulae* new species, Dermestidae

Holotype. ♀, St. Paul, Minnesota, October 10, 1938 (Collector H. E. Milliron). Deposited in the Collection of the University of Minnesota as type number 211.

Paratypes, 4 ♀♀, St. Paul, Minnesota, July 10, 1938 (Collector H. H. Shepard). 27 ♀♀, St. Paul, Minnesota, August 8, September 16, October 1, October 10, October 14 and November 7, 1938 (Collector H. E. Milliron).

Specimens were sent to the United States National Museum for study; to the British Museum to be compared with species of *Megatoma* and those of related genera; to the Museum of

Comparative Zoology, Harvard University, for comparison with the type of *Perimegatoma belfragei* Horn and finally, to the Muséum National d'Histoire Naturelle, Paris. This species is distinctly different from any of the dermestids represented in their collections.

The body outline of *P. vespulae* is like that of species of *Megatoma* and *Perimegatoma*, two closely allied genera. There is also a resemblance with species of *Attagenus* but the long, first segment of the tarsi and the lobed prosternum of *P. vespulae* eliminate it from that genus. The absence of antennal fossae excludes the possibility that it belongs in the exotic genus *Megatoma*, the members of which are supposed to show this character as well as a three-segmented club in the female. In 1875, Horn erected the genus *Perimegatoma* for the reception of North American species which possess all the features of *Megatoma*, except the antennal fossae. The use of this character to distinguish these two genera seems, however, to be open to question; several specimens of *Megatoma undata* (L.), examined by the writer, do not possess sharply defined antennal fossae, although the entire hypomeron is decidedly more deeply concave as compared with species of *Perimegatoma* examined. The much more gradual concavity of the hypomeron of *P. vespulae* reveals a closer affinity with *Perimegatoma*.

All species which are now included in Horn's genus have a distinct three-segmented antennal club, except *P. belfragei* which has five segments in the club. In 1900, Colonel Casey was inclined to believe *belfragei* formed the type of a new genus but hesitated to make it such. The salient features of *P. vespulae* that readily separate it from all other species of the genus are the four-segmented antennal club, and the entirely different type of pubescence. Much of the difficulty in placing this species has arisen as a result of the lack of specimens representing the male sex.

Mature larvae average about 5–6 mm. in length, are testaceous to reddish brown in color and somewhat resemble those of *Trogoderma* in general appearance. The dorsum of the body, especially the sides of anterior segments, is densely covered with a barbed pubescence, each hair terminating in a cone-like end. Brush-like patches of this type of pubescence entirely cover the last four abdominal tergites as is the case in several other genera. Long, stiff pubescence of the ordinary type forms tufts at the sides of each segment and extends across the tergites

as a single row of hairs, medially situated, except on anterior segments where it becomes more basal. The venter bears closely appressed pubescence. The caudal tuft is spiral especially in earlier stages. Apparently the larvae molt at least five to seven times before reaching maturity.

Some very interesting and surprising observations have been made in regard to the sex of the specimens taken from both the nest and the cultures. The fifty adults which have emerged to date have all shown the female genitalia, except one which has proved to be abnormal. A study of the pupae did not reveal any sex differences. In spite of the failure to discover specimens of the male sex, early instar larvae have regularly appeared in the cultures.

On November 7th a single pupa was placed in an eight-dram homeopathic vial which was stoppered with a cork and kept at room temperature. The adult emerged November 17th and after three days hardened and changed to the normal black and brown color. Dried insect specimens, sterilized by heat, were placed in the vial in order to stimulate oviposition on a natural food medium. Seven eggs were deposited on or near November 24th, four on the 25th and three on the 26th. Oviposition then ceased and the adult continued to live for a week or more. There was a tendency to deposit eggs in crevices or creases of the dried insects. Three eggs were inserted between one of the middle tibiae and the body, and two in the cervical region of a specimen. The others had fallen out of the crevices or were dropped freely on the bottom of the vial. They were very soft when freshly laid but after two or three days became firmer. Prior to hatching, the tip of each became light reddish brown, followed by a darkening of the sides. The egg stage lasts for approximately two weeks at this temperature. Between December 7–9th, a total of eleven larvae hatched, seven of which died within a few days for some unknown reason. The remaining larvae from this culture have now been reared through the fourth instar.

Other individual pupae have been isolated from time to time and resulted in adults which reproduced without mating. The observations and data collected are conclusive evidence that the species is parthenogenetic, a condition which, to the knowledge of the writer, has never been reported as occurring in the Dermestidae.

The nest of *V. arenaria* in which *P. vespulae* was found is

said to have been in the possession of the department for a period of from twenty to twenty-five years and has been used occasionally for class demonstration. During the latter part of last summer, when it was closely examined for additional material, five adults were found concealed between the layers of paper composing the nest, and many larvae in all stages of development were obtained for new cultures. How and when the original infestation occurred is unknown, but the number of cast off larval skins and the quantity of excreta in the nest indicated that it had taken place several years before. The remains of the vespids and their excreta in the nest constituted the only known food.

A statement regarding the exact manner of introduction would be at present mere speculation, but there are two possible ways by which the species might have been brought into the laboratory; in foreign or domestic collections received by the department or in either nests collected subsequently or wood samples illustrating insect injuries. Infestation from the field seems possible in view of the fact that numerous specimens of *Perimegatoma cylindrica* Kby. have been taken by Mr. Ralph Hopping from yellow pine infested with *Dendroctonus*. Presumably this dermestid infestation occurred in the field for he seemed to think they evidently breed in or under bark. Occasional records of *Megatoma* taken from andrenid or other hymenopterous insect nests may be found in the European literature.

Thus far, the only known occurrence of this insect was in the wasp nest mentioned, but the ability to maintain itself under adverse conditions and the comparatively short life cycle indicate a potential museum pest, especially in neglected collections.

DIE PHYSIOLOGIE DES WACHSTUMS UND DER BEWEGUNGEN, by ERWIN BUNNING. (Vol. 2 of "Lehrbuch der Pflanzenphysiologie.") Pages vi and 267, 233 text figs. 1939. For sale by Hirschwaldsche Buchhandlung. Unter den Linden 60, Berlin NW 7. Price, unbound, about RM 18, bound, about RM 19.80.

We give this brief notice of a volume as yet not off the press, first to fill space, second because it appears to cover ground of a very general interest in biological theory.—C.H.K.

REARING THE CADDICE FLY, LIMNEPHILUS INDIVISUS WALKER AND ITS HYMENOPTEROUS PARASITE HEMITELES BIANNULATUS GRAV.[1]

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The problem of rearing caddice fly larvae and correlating the immature and adult stages of the Minnesota species has been a graduate student project in the Division of Entomology and Economic Zoology at the University of Minnesota for six or seven years. Mr. Winston Elkins was the first to work on the problem and published his results in 1936. Mr. Donald Denning is following up the work of Mr. Elkins and published his first results in 1937. Some six or seven years ago caddice fly larvae with a log-cabin type of case were noticed in the temporary ponds in the forest at Itasca Park, Minnesota. Tremendous numbers of these cases were present in the ponds. Owing to the fact that none of the interested persons could spend any time at Itasca Park during the several weeks at the period when the larvae transformed to pupae and later to adults no attempt was made to rear the species through at Itasca Park or to make observations of it in the temporary ponds. Numerous attempts were made to get these log-cabin cases containing larvae to our St. Paul laboratory and to rear the larvae to the adult stage, but in every instance they either died while being transported from Itasca Park or shortly after reaching the laboratory. In transporting these larvae within their cases the latter were placed in pint jars containing water from the ponds and brought by automobile to St. Paul. Care was taken not to crowd the cases in the jars and thus bring about an oxygen deficiency in the water. The distance from Itasca Park to St. Paul is two hundred and twenty-five miles and requires a drive of from five to eight hours.

During the year 1938 the senior author was at Itasca Park from June 13 to July 22 teaching at the Forestry School. Mr. Denning called attention to the fact that he had not been able to rear this log-cabin caddice fly and inquired if it would be possible for me to do anything

[1]Paper No. 1665 Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2]The rearing of *Limnephilus indivisus* Walker was done by the senior author; that of *Hemiteles biannulatus* Grav. by the junior author.

with the problem while I was at Itasca Park. On June 16 I located about half a mile from the Itasca Park insectary a fairly large temporary pond which was heavily populated with log-cabin cases. This temporary pond was located in a swamp-hardwood forest, a short distance from a large floating bog. Approximately one hundred and fifty cases were collected and taken to the insectary. Two types of cases were collected. Nearly all were of the log-cabin type, but a very few were made of shells and bore no resemblance to the others. It was assumed at first that the shell cases contained a different species but later it was learned that the two were the same when exactly similar adults were reared from both. Since no equipment was at hand, glass battery jars were used for aquaria and the cases were submerged in water in these for rearing. All the cases were examined and it was found that the majority were still in the larval stage, a few were in the prepupal stage, and a few had transformed to pupae. In examining the cases it was noted that one contained a hymenopterous cocoon. The cocoon enclosed a prepupa. It was turned over to the junior author for study and rearing and will be referred to later.

By June 25 all of the caddice fly larvae, prepupae and pupae in the battery jars had died. Since the aquaria were not balanced and since no oxygen had been added to the water it is probable that they died of suffocation. It was then decided to make a new attempt to rear this insect and since the only means available of adding oxygen to the water in the aquaria was by means of a tire pump, which happened to be at hand, this was used. It was made more efficient by cutting a piece of balsa wood to fit the end of the rubber tube leading from the pump and fastened in so that when that end was put in an aquarium a finely divided stream of air bubbles came through the water. In order to reduce the amount of labor required the pump was fastened in a stationary position so that it would not fall over and a weight attached to the plunger. When the latter was pulled clear out the weight would gradually force the plunger down one full stroke. Since this took approximately thirty seconds a stream of finely divided air bubbles passed through the water continuously for that length of time on the stroke downward. It was decided, on a purely arbitrary basis, to give each aquarium thirty strokes per day.

The pond was again visited and approximately three hundred cases collected. On visiting the pond this second time it was noted that the level of the water had gone down some eight or ten inches and many of the log-cabin cases were lying on top of the muck at the edge of the pond, but since the muck was moist the cases had not dried out, and their inhabitants were alive. This observation suggested the idea that perhaps the cases did not need to be submerged in water in order for the larvae and pupae to live, but that enough moisture to keep the tracheal gills moist might be sufficient. With this in mind seven log-cabin cases were put in a jar with only a thin layer of water in the bottom, so that the cases in contact with the water would be kept moist by capillary action. The remainder of the cases were placed in three battery jar aquaria and air was pumped into the water once daily.

This second lot of cases was started in the various aquaria on June 25. The first adults emerged on June 27. Six adults emerged on June 28

with both sexes represented. On July 1 an adult emerged from the jar in which the cases were only moist and demonstrated that it was not necessary to keep them submerged in water. The senior author returned to St. Paul on July 2 and was able to identify the adult as *Limnephilus indivisus* Walker, which has been reared by Lloyd (1915, 1921) from a log-cabin type of case present in temporary ponds in New York. This identification has been verified by Mr. Denning and Dr. Cornelius Betten. Several additional parasitized cases had been discovered since June 16 and these were also brought to St. Paul and turned over to the junior author. Upon returning to Itasca Park on July 5 it was found that numerous adults had emerged from the aquaria and that another had emerged from the moist jar. It was then decided to make another collection of cases and attempt a mass rearing in shallow pans in which the cases were not submerged in water but kept moist by adding a slight amount of water each day to the pans. Several hundred cases were collected on July 9. On this date the majority of the cases contained pupae, a few contained prepupae, and a few larvae. Five pie tins were used for holding the cases and each was placed beneath a screen wire cage. The five pie tins held only about half of the cases and since no more pie tins were available the remaining cases were dumped into a large oblong pan about two inches deep piled one on top of the other. On July 10 the adults began to emerge not only from the pie tins which had the cases arranged in a single layer, but also from the large pan where they were massed together. There was an increasing emergence each day until July 13 when fifty were found in the cages. Adults had emerged from nearly all the cases when the project had to be terminated on July 22. Approximately three hundred and fifty adult specimens had been obtained.

It is our belief that the success of this mass rearing experiment was due to the greatly increased oxygen supply made available by exposing the cases directly to the air. When the immature stages are exposed in this way with the tracheal gills kept constantly moist, it is probable that oxygen from the air is taken up very rapidly by the greatly increased surface film of water on the gills. Thus, a greater oxygen supply for each larva is available in this increased area of surface film than is present in a water environment where they are completely submerged.

It was noticed that nearly all of the adults emerged at night. There was only an occasional emergence during the day. The adults were very secretive after they were dried and had become active. They would crawl into all sorts of cracks and crevices and if one escaped from a cage and was lost sight of for a few seconds it was almost impossible to recover it in the insectary. It was also noticed that although the number of log-cabin cases in the temporary pond was exceedingly large that it was very difficult to find adults in the vicinity of the pond during the time when they were emerging in the insectary. A few were obtained but only after considerable search. Their scarcity was attributed to their secretiveness. They were probably hidden away in cracks and crevices in the trees and therefore difficult to find. It was also noticed that they were not attracted to lights at night although there were a number of electric lights burning in the vicinity and many different species of caddice flies and other insects were so collected.

After learning that *Limnephilus indivisus* could be reared through by keeping the cases only moist and not submerging them in water the conclusion was reached that the difficulty in transporting these cases from Itasca Park to St. Paul was due to one or more of the following factors; first, oxygen deficiency in the water; second, increase in temperature of the water; and third, the violent shaking of the cases. It was then decided to try transporting the cases in moist sphagnum moss. Such a medium would keep the cases moist, evaporation from the surface of the moss would tend to prevent any decided increase in temperature, and the moss itself would reduce any injurious shaking around of the cases. Cases packed in this way were brought to St. Paul the last part of July in excellent condition and adults were obtained in the laboratory shortly afterwards. This was also tried with May flies, other species of stream inhabiting caddice flies and *Simulium* larvae. We have been able to transport these immature stages for distances up to three and four hundred miles and over a period of two or three days without losing any of our material. When they reach our St. Paul laboratory they are placed in containers with air continually passing through the water, the air being supplied by a compressed air system. This method has been described by Denning (1937). We have had very successful results in rearing such material to the adult stage.

Two conclusions seem to be justified from our experience with this caddice fly: first, caddice flies living in temporary ponds and possibly many other aquatic insects living in various aquatic environments, can be reared to the adult stage without keeping them submerged, the only requirement being that the case be kept in contact with a thin layer of water which by capillary action will keep the enclosed larva or pupa and its tracheal gills moist; second, most if not all, aquatic insects with tracheal gills can be transported long distances in moist sphagnum moss without any noticeable mortality.

THE HYMENOPTEROUS PARASITE

After the first case of *Limnephilus indivisus* was discovered parasitised by what was tentatively determined as *Hemiteles biannulatus* Grav. thorough searches for additional parasitised cases were made several times during the months of June and July. Most of the parasitised cases were collected from among those exposed after the water had receded, and which were near the edge of the pond. Invariably such cases were partially or completely covered with mosses. Closer observation showed that they were also closed at both ends. The parasitized cases were much more numerous in one section of the pond than elsewhere, but the average parasitism of all caddice flies appeared to be less than two per cent. Forty to fifty parasitised cases were discovered in this one pond.

The first lot of parasite cocoons was brought to the St. Paul laboratory in June. A few of these were submerged in water and the others kept in moist sphagnum moss at room temperature. A dead adult female in poor condition was discovered on the surface of the water in early July. No further emergence from cocoons in water has occurred. On July 7 a female emerged from the cocoons in sphagnum moss. The

second lot of cocoons was brought to the laboratory on July 22, and kept in moss at 0–5 degrees centigrade for several weeks after which the temperature was raised to 25 degrees centigrade. By this method two females and a male were obtained. There still remain about twenty cocoons from which nothing has emerged to date.

It is possible that most of the parasitism occurs when the water level in the pond is low and the host cases are not entirely submerged, but there is no positive evidence to indicate that this is true. Data at hand are too meager to permit drawing any definite conclusions regarding the biology of the parasite. Attempts to capture adult parasites by sweeping nearby vegetation were unsuccessful during any of the visits to the pond, indicating that the adult population was not very abundant.

The parasite cocoon, which fits snugly into the posterior half of the caddice fly case, is 7 mm. long and 3 mm. in diameter, cylindrical and truncate at both ends. It is constructed of at least two layers of silk, the outer one of which is dark ashen gray and impervious to water. Generally all that remains in the host case is the parasite cocoon, and anterior to it, the pupal skin of the host. Most of the cocoons that were opened contained larvae or prepupae; a few contained adults ready to emerge.

The female of the parasite is 5–6 mm. long. The head, thorax and abdominal tergites beyond the third are black. The first three abdominal tergites are red, and the legs are reddish brown. The male differs in superficial appearance from the female only in that the antennae are not ringed with white and the red of the abdomen extends onto the basal half of the fourth tergite. Two females check perfectly with a specimen of *H. biannulatus* Grav. (determined by Ruthe and Morley) borrowed from the British Museum (Natural History). The third female is either a variety of *biannulatus* or a closely related new species.

Apparently the only record of *H. biannulatus* occurring in the United States is that published by Roman (1924) without host data. Most of the investigations in regard to parasitism of Trichoptera have been conducted by European workers. As a result of those researches we know of three ichneumonid parasites which select various species of caddice flies as their hosts. Von Siebold (1858) reported *Agriotypus armatus* Walker as a parasite of *Trichostoma picicorne* Pictet (=*Silo pallipes* F.); Ritsema (1870) reported *Phygadeuon* sp. parasitising *Enoicycla pusilla* Burmeister; and Siltala and Nielsen (1906) found that *Limnephilus griseus* L. and several other species of caddice flies were parasitised by *Hemiteles biannulatus* Grav. the biology of which is included in their publication. In the United States, Sibley (1926) reported collecting a parasitised case of *Platycentropus maculipennis* Kolenati and gave a brief description of the cocoon of the parasite. Apparently adults of this species have not yet been reared.

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PROBLEMS IN ANIMAL ECOLOGY, by F. S. BODENHEIMER, 5.75 x 9 inches, pp. i-vii + 183, 28 text figs. 1938. Published by the OXFORD UNIVERSITY PRESS, 114 Fifth Ave., New York City. Price, $4.00.

This is a volume which should be studied carefully by all economic entomologists whose life work deals with varying populations, as it digs up oversights and biases in previous studies of such subjects as biotic potential, environmental pressure, growth and decay of populations, etc. It points out the complexities which usually cover the weak spots in previous research in this field. As the author states it: "The present book deals with some problems of animal ecology which—owing to their intrinsic or their formal difficulties—have been neglected."

The contents runs as follows: I. *Physiological and Ecological Life Tables and Connected Problems;* this includes: 1. Physiological life-expectation; 2. Life intensity and longevity; 3. Ecological life-expectation; 4. Age-distribution in animal populations; 5. Relation between the three ecological ages. II. *The Life-History and Its Ecological Interpretation Today;* 1. The physical ecology of the life-cycle; 2. Life cycles of coccinellid beetles in Palestine; 3. Applications of the climograph; 4. The epidemiological bonitation of *Ceratitis capitata;* 5. Sense ecology and behavior. III. *What Really Occurs in the Drosophila Bottle? A Further Approach to a Complete Population Analysis:* 1. Drosophila as a model in population studies; 2. Biological constants in the Palestine strain of Drosophila; 3. Population growth in the Palestine strain; 4. Total population count in the Drosophila bottle and its results; 5. Dynamics of population growth and decrease in the Drosophila bottle; 6. Comparison and conclusions. IV. *Biological Equilibrium in Nature and Biological Control:* 1. The case for biological equilibrium; 2. The case for climatic control; 3. Analysis of recently published facts on biological control; 4. Analysis of recently published facts on biological equilibrium; 5. Arguments arising from recent discussions on biological equilibrium; 6. Biological control; 7. Conclusions. V. *Is the Animal Community a Dynamic or a Statical Conception?* 1. Description of marine bottom communities; 2. Description of some terrestrial associations; 3. The habitat concept of animal communities; 4. Empirical species combination, as characteristic of the animal community; 5. Do coactions within the animal community justify the superorganistic conception? VI. *The Interaction of Environment and Heredity Within the Organism:* 1. Actual relations between ecology and genetics; 2. Heredity of important ecological characters; 3. The interaction of environment and heredity in the diapause; 4. The interaction of environment and heredity in sex-determination; 5. The interaction of environment and heredity on geographical variation; 6. The problem of adaptation; 7. Outlook.

We have introduced this detailed list of captions because each heads an interesting discussion. All recent research indicates that the biological world is vastly more intricate than summary or particulate behavior of living organisms would indicate. Biotic relationships have to be analyzed and reanalyzed. The volume is very well documented so that the author's argument is on very specific problems but in a very wide ecological field. An anylitically critical review of any such subject is usually very helpful. We recommend this work as such a helpful volume in the philosophy of ecology.—C. H. K.

NOTES ON FORMICA (NEOFORMICA) MOKI WHEELER, WITH DESCRIPTION OF A NEW SUBSPECIES

(Hymenoptera: Formicidae)

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Recently I received for determination three workers and four callows of an undescribed ant closely related to *Formica moki* Wheeler. These specimens were collected by Falconer Smith at Leavenworth, Wash., in an arid region somewhat similar to the regions in which live our honey ants, *Myrmecocystus* spp. The similarity of appearance is indeed very striking between certain species of *Myrmecocystus*, *Formica moki*, and the new subspecies. Wheeler was so puzzled as to the proper subgeneric assignment of *moki* that he at first placed the species in the *rufa* group of the typical subgenus, and later transferred it to the subgenus *Neoformica* Wheeler. The cotypes of *moki* were collected in the Grand Canyon of Arizona at an altitude of 5,000 to 7,000 feet (Bull. Amer. Mus. Nat. Hist. 22: 343–344, 1906). The uncertainty regarding the correct systematic position of *moki* is shown in the following quotation from Wheeler: "This species seems to belong to the *Formica rufa* group although certain characters ally it with *F. fusca*. At first sight it resembles rather deeply colored specimens of the variety *neoclara* Emery of the latter species, but differs from this and all the other North American *Formicae* known to me in the very low and flat thorax and the length of the mesoepinotal constriction. In these respects it approaches the forms of the *pallide-fulva* group, but the surface of the body is subopaque as in the smaller species allied to *F. rufa*. It will be impossible to assign *moki* to a precise position until the female is discovered."

Later, in his "A Revision of the genus *Formica* (Linn.) Mayr" (Bull. Mus. Comp. Zool. 53: 560, 1913), he wrote as follows: "This species seems to belong in the *pallide-fulva* group (subgenus *Neoformica*—author), although the sculpture of the body is very unlike that of the preceding species (species of *Neoformica*—author). Superficially it resembles *F. rufibarbis*, but the head, thorax, and antennae are much more like those of *pallide-fulva*. There is, however, much that recalls *Myrmeco-*

cystus in the structure of the thorax seen in profile." After a study of cotypes of *moki* and specimens of the new subspecies described below, I believe the species best fit the characters of *Neoformica*. That they are related to *Neoformica* is shown by the following characters of the worker: Large eyes, slender thorax with weak mesoepinotal constriction, and long appendages. The worker differs, however, from the other forms of *Neoformica* in its distinctly shagreened, subopaque body, which in certain lights has a somewhat metallic luster. The body pubescence is also denser. There is no other species of *Neoformica* that approaches *moki* in coloration; furthermore, the forms of this subgenus are confined, almost without exception, to the southern and more eastern sections of the United States, in habitats very different from those of *moki* and the new subspecies. It may be necessary later to erect a new subgenus for these ants but I would hesitate to do so until a larger collection is available, and especially until the male and queen are known.

After an examination of three of Wheeler's cotypes I find they differ in several respects from his original description. The differences are as follows: Maxillary palpi, 6-segmented instead of 5-segmented, mandibles 7- or 8-toothed instead of always 8-toothed, epinotum having base and declivity nearly subequal instead of base nearly twice as long as declivity.

A redescription of *moki* is given below. Characters are also furnished for distinguishing the new subspecies from *moki*.

Formica (Neoformica) moki Wheeler

Formica moki Wheeler, Bull. Amer. Mus. Nat. Hist. 22: 343–344 (1906), *worker;* Bull. Mus. Comp. Zool. 53: 558–560 (1913), *worker.*

Worker—Length 4–5.5 mm.

Head, exclusive of mandibles, one-seventh to one-ninth longer than broad, narrower in front than behind, with entire and gently rounded posterior border, rounded posterior angles, and weakly convex sides. Eye large, convex, oblong, little more than its greatest diameter from base of mandible. Antenna long and slender, scape approximately as long as the combined lengths of the first 7 or 8 funicular segments; middle funicular segments about twice as long as wide. Clypeus sharply carinate, anterior border entire, projecting medianly. Frontal and ocellar triangles almost equilateral. Frontal carinae slightly diverging behind. A faint frontal furrow often extending as far backward as anterior ocellus. Mandible 7- or 8-toothed. Maxillary palpus long, slender, 6-segmented. Thorax long, narrow; mesoepinotal constriction shallow; base and declivity of epinotum subequal, the base sloping to meet the declivity in an obtuse angle. Pronotum viewed from above almost as long as broad; mesonotum approximately one and-half times as long as broad. Petiole with a moderately convex anterior surface, and

flat posterior surface, the two meeting above to form a sharp, straight or sometimes feebly rounded superior border. Gaster small. Legs long and slender.

Subopaque, finely and densely shagreened; mandibles, sides of clypeus, and frontal area slightly shining in certain lights. Mandibles densely striate, and also coarsely punctate. Posterior dorsal surface of head and the gaster with a metallic or bronzy luster in certain lights.

Hairs grayish, sparse, erect, present on clypeus, dorsal surface of head, coxa, trochanter, and flexor surfaces of femora and tibiae, and on gaster; hairs on mandibles suberect; hairs on gaster shorter than on venter and at apex. Pubescence grayish, fine and dense, covering all parts of body, but densest on gaster.

Dull ferruginous; dorsal surface of head posteriorly, and the petiole, gaster, and legs dark brown; in some lights parts of the thorax may have a brownish or infuscated cast.

Type locality.—Bright Angel Trail, Grand Canyon, Ariz., 5,500–7,000 feet (W. M. Wheeler).

Other localities.—Prescott, Ariz. (W. M. Wheeler); Milford, Utah (J. C. Bradley).

The redescription is based on three cotype specimens lent me through the kindness of Nathan Banks, of the Museum of Comparative Zoology.

Wheeler says, "*F. moki* nests under stones and forms colonies about the size of those of *F. pallide-fulva* and its various subspecies and varieties. It probably represents this species in the dry deserts of the Southwest, but is certainly a much rarer ant."

Formica (Neoformica) moki subsp. **xerophila**, new subspecies

Worker.—Length 5.3–5.6 mm.

Similar to *moki* except for the following differences: Mandible uniformly 8-toothed in all specimens examined; petiole thicker anteroposteriorly, and with blunter, more rounded, and feebly notched superior border; pubescence of body apparently denser, therefore more distinct; general color blackish with anterior part of head, and the antennae, tibiae, and tarsi reddish brown; body, especially the posterior dorsal portion of head, and the gaster, with a metallic luster in certain lights.

Type locality.—Leavenworth, Wash. (Falconer Smith).

Cotypes.—No. 53290, U. S. National Museum.

Described from three workers and four callows collected from the soil beneath a piece of cow dung at an elevation of 1,165 feet. This locality is in a rugged mountainous area of the arid Transition Zone. The dominant trees here are *Pinus ponderosa* with occasional shrubby trees, probably of the genus *Alnus*. The nest was fully exposed to the sun, except for the covering of cow dung.

The worker of this subspecies can be distinguished from that of *moki* by its color, also by the shape of the petiole, as well as by differences in pubescence and luster.

W. S. Creighton, who has also compared specimens of this ant with cotypes of *moki* agrees with me that the ant is a new form. Dr. Creighton would, however, assign it specific rather than subspecific rank.

MEDICAL ENTOMOLOGY WITH SPECIAL REFERENCE TO THE HEALTH AND WELL-BEING OF MAN AND ANIMALS, by WILLIAM B. HERMS. Third edition, Pages i-xix and 1–582, 196 text figures, 9½x6, cloth. 1939. Published by THE MACMILLAN COMPANY, 60 Fifth Ave., New York, N. Y. Price $5.50.

This is a complete revision of the second edition which was called Medical and Veterinary Entomology. The omission of "veterinary" from the present title does not mean that less attention is given to the arthropod vectors of diseases of animals. The title was changed only for the sake of brevity. Being the third edition of a book by a man who has had long experience in medical entomology, it should be good, and it looks good to this inexpert reviewer.

The student is introduced to the subject in the first 69 pages, learning something of the history, scope and method of medical entomology, the nature and kinds of parasites and parasitism, how insects and arachnids cause and carry disease, the structure, development and classification of insects and arachnids, and the various types of insect mouth parts, the last being clearly and completely illustrated. The next 352 pages deal with insects that may cause disease in man or animals, including identification and classification, life history, and control, as well as information on parasites and transmission and nature of diseases. The insects are arranged in the usual order of classification from cockroaches to fleas, though beetles are placed with cockroaches in chapter 7. It is interesting to note that Diptera require 70 per cent of the space on insects, with mosquitoes leading all other groups with 67 pages followed by houseflies with 52 pages. The general subject of myiasis is treated in a separate chapter within Diptera. A chapter on ticks and one on mites follow the insects. The next to the last chapter deals with venomous and urticarial arthropods and the last with arthropods in medical practice.

To take a fair sample of this book one should choose arthropods of the greatest medical importance to which Professor Herms has given the most attention. This reviewer's limited personal knowledge, however, required him to study the sections on cockroaches and bedbugs which are not particularly important from the medical point of view. Little fault is to be found with these sections, though they could have been made more informative. It might be pointed out that the ootheca of cockroaches is not chitinous; i. e., does not contain chitin. There is no experimental evidence that sodium fluoride acts as a stomach poison against cockroaches; on the contrary, Hockenyos as well as Siegler and Munger have shown that this compound probably acts as a contact poison, the powder ingested by the roach while cleaning its appendages being insufficient to kill. Under control of cockroaches trapping is discussed at some length, but the much more important use of liquid insecticides, phosphorus paste, pyrethrum powder and fumigants is not mentioned. Under fumigation with hydrocyanic acid gas for bedbug control, the author is to be commended for the following statement: "The work should be done only by persons well informed about the use of this fumigant, preferably by a licensed pest control operator." The reader, however, will not become "well informed" by reading the directions given by Professor Herms, who has not sufficiently stressed hazards involved or precautions to be taken. This reviewer does not know of a book in English that gives thorough and up-to-date information on chemical control of insects affecting man and animals.

In general appearance this book makes an excellent impression. The illustrations, particularly the line drawings, are clear and informative, a bibliography follows each chapter, and a long subject and author index completes the book.

—F. L. C.

A CORIXID FROM DEEP WATER

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On two or three occasions I have received for determination Corixidae taken from considerable depths of water in Lake Erie. Several years ago Dr. C. H. Kennedy sent some examples to me and more recently Dr. V. E. Shelford forwarded five collections made in Lake Erie, and I consider the information of some interest. The species is *Arctocorixa lineata* Forster described in 1771. It is a small Corixid strikingly marked by three longitudinal dark markings on the hemelytra, two of them on the corium and one on the clavus, and is a species often taken in rivers having considerable current.

This is the species that Mr. Walley (Can. Ent., LXI, pp. 34–36, 1929) figures under the name *Arctocorixa bilineata* (Provancher). In 1930 Walley (Bull. Brooklyn Ent. Soc., XXV, pp. 203–206) proposed *Arctocorixa trilineata* (Provancher) 1872 as a synonym of *Arctocorixa lineata* Forster 1771. Many years ago I concluded that *Arctocorixa bilineata* (Provancher) is a synonym of *Arctocorixa lineata* (Forster). I still believe this is correct. Forster's brief description of his *Notonecta lineata* in *Novae Species Insectorum*, Centuria I, p. 70, London, 1771, says:

"Pallide flava, elytris concoloribus; maculis nebulosis fuscis tribus longitudinalibus. Habitat in aquis provinciae Noveboracensis in America Septentrionali. Magintudo 1/6 pollicis s. unciae Anglicanae. Antennae parvae sub capite, pone oculos, duorum articulorum, extimo clavato. Caput obtusum, flavum. Oculi brunnei. Thorax flavus, lineis tribus transversis fuscis. Elytra flexilia flava, punctis nebulosis fuscis, in lineas tres longitudinales digestis. Alae inferiores albae, pellucidae. Abdomen, Pedes, & Pectus pallide flava."

The size, 1/6 of an inch, would be about 4.23 mm., which is nearer the *A. bilineata* (Provancher) length of 4 mm. than it is the *A. trilineata* (Provancher) length of 6 mm. The three-lined pronotum fits *A. bilineata* (Provancher) often, but very seldom can one find *A. trilineata* (Provancher) with so few. If one considers the hemelytra as a whole (not just the corium) there are three longitudinal brown stripes, the inner one on the clavus and margin beyond in the smaller species. Moreover, Forster

says that the antennae in his *N. lineata* are two-segmented, the terminal segment clavate. In *A. bilineata* (Provancher) the antennae are three-segmented, the terminal segment being large and clavate, whereas in *A. trilineata* (Provancher) the antennae are four-segmented, the terminal segment being much smaller than the third as is usual in our Corixids. The fact that Forster did not see that the basal part is really two short segments is not surprising, since the antenna has the appearance of being two-segmented. If his species had possessed an antenna like *A. trilineata* (Provancher), he could not have described it as he did. Thus size, pattern, and structure favor the conclusion that *A. bilineata* (Provancher) and not *A. trilineata* (Provancher) is the synonym of *A. lineata* Forster.

Dr. Shelford's collections were made at Put-in-Bay, Ohio, and consisted of the following: "July 21, 1937, Sta. No. 57, Sand bottom at depth of 35 feet," 5 specimens (3 ♂ and 2 ♀); "July 29, 1937, Sta. No. 83, Sand, gravel, shell at depth of 31 feet," 2 ♀ ♀; "July 30, 1937, Sta. No. 88, trawled from 27 feet depth-mud bottom," 1 ♀; "August 3, 1937, Sta. No. 97, Rock, gravel, mud at depth of 18 feet," 2 ♀ ♀; "August 4, 1937, Sta. No. 101, Sand bottom-dredged from 14 feet depth," 1 ♂, 2 ♀ ♀.

It would be interesting to find nymphs also at these depths ranging from 14 to 35 feet.

GERMAN-ENGLISH SCIENCE DICTIONARY FOR STUDENTS IN THE AGRICULTURAL, BIOLOGICAL AND PHYSICAL SCIENCES, by Louis De Vries. 1939. Pages x and 473. 5.25 x 7.25 inches. Published by McGraw-Hill Book Company, Inc., 330 W. 42nd St., New York, N. Y. Price, $3.00.

De Vries' German-English Science Dictionary contains 48,000 entries of German words and compounds used in agriculture, biology and the physical sciences. We have checked the first hundred entries under the letter G and find that only thirty are found in the widely used Heath's German Dictionary. This indicates that the De Vries volume will be three times as useful in translating technical terms as is Heath's Germany Dictionary. However, the struggling student must remember that a lexicon of technical terms is no longer a dictionary of every-day language. It contains only technical terms.

Professor Louis De Vries is Professor of Modern Languages in Iowa State College. He acknowledges assistance from thirty-four members of Graduate Faculty of that institution. He sheds criticism by quoting the incisive remark of Doctor Samuel Johnson: "Every other author may aspire to praise, the lexicographer can only hope to escape reproach." De Vries has not as yet been overtaken by reproach.

As an appendix are given five pages of German abbreviations with the full German and English expressions. In the introduction under "Reference Works" are listed over thirty German-English and German technical and scientific dictionaries. We have long wished for such a list. Here it is but in another dictionary, naturally without helpful prices and the addresses of publishers.

This dictionary will be found a convenience in the library of every scientific laboratory and in that of every research man who reads technical German with any regularity.—C. H. K.

REPORT ON SOME WATER BUGS FROM COSTA RICA, C. A.

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A small consignment of water bugs collected near San Isidro del General at elevations of from 2000 to 2300 feet by Dean L. Rounds has been received recently. This lot has been of particular interest to me because it contains *Potamobates unidentatus* Champion, a species known previously only by the types in the British Museum. Some other records are also worth noting.

Gerridae

Platygerris asymmetricus Hungerford. (Bull. Brooklyn Ent. Soc., Vol. XXVII, pp. 178–180, 1932.) 19 males, 21 females. (2 ♂♂ and 6 ♀♀ winged). Since the type series was wingless I am making *morphotypes* of these long winged forms.

They measure 10 mm. long from tip to tip which gives them the appearance of being much larger than the wingless forms which are only 7 mm. long. The tan spot on head and line on anterior lobe of pronotum as in wingless forms; rear margin of pronotum rounded. Hemelytra smoky brown to black, the anterior margins lighter brown. The hind wings smaller and extending beyond the abdominal tip not quite half as far as the front wings.

Morphotypes in Francis Huntington Snow Entomological Museum.

Potamobates tridentatus Esaki. (Annales Musei Nationalis Hungarici XXIII, pp. 251–254, 1926.) 3 males, 4 females. This species was described from Costa Rica. I have 3 specimens also from Fort Clayton, C. Z., taken in 1933 by Capt. R. F. Edwards.

Potamobates unidentatus Champion. (Biol. Centr.-Amer. Hem. Het. II, pp 154–155, 1901.) 3 males and 8 females, all wingless. This species was described from Panama and not again reported until now. A pair of these were sent to Mr. China of the British Museum for comparison with Champion's types.

Limnogonus guerini (L. & S.). (Cat. Gén. Hémip. III p. 61, 1896). 3 males and 2 females.

Limnogonus recens Drake & Harris. (Annals Carnegie Museum XXIII, pp. 207–208, 1934.) 1 male. This species has been reported from British Honduras, Guatemala, and Panama.

Veliidae

Rhagovelia uncinata Champion. (Biol. Centr.-Amer. Hem. Het. II, pp. 138–139, 1901.) 4 males. This species was described from Panama and is new to our collection.

Rhagovelia regalis Drake & Harris. (Proc. Biol., Soc. Washington XL, p. 137, 1927.) 6 males, 4 females.

Rhagovelia angustipes Uhler. (Proc. London Zool. Soc. for 1894, p. 215.) 1 female.

Naucoridae

Pelocoris femoratus P. B. (Ins. rec. Afr. Amer., p. 237, 1805.) 2 males, 1 female.

Cryptocricus n. sp. 5 males, 9 females.

Ambrysus n. sp. 4 males, 5 females.

Notonectidae

Notonecta indica Linn. (Mantissa Plantarum II, p. 534, 1771.) 2 males, 4 females.

Buenoa pallipes Fabr. (Syst. Rhyng, p. 103, 1803.) 7 males, 1 female.

Corixidae

Centrocorisa nigripennis (Fabr.) (Syst. Rhyng., p. 105, 1803.) 3 males. Studies published by Dr. Lundblad and Dr. Jaczewski seen to conclude that there is only one good species in the genus. Dr. Jaczewski (1933) concluded its name should be *Centrocorisa cubae* Guér., 1844. However, Fabricius' name seems to have been overlooked. I saw the Fabrician types in Copenhagen in 1928.

THE RATE OF REGENERATION IN THE GERMAN ROACH

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Regeneration, the ability to replace lost or injured appendages, is commonly acknowledged as being spread widely throughout the insect world, but specific citations are surprisingly meagre. Even those which are available are mostly mere records of occurrence, while the majority of the fundamental research in this connection has dealt with the Crustacea. Woodruff (1937) attempted to summarize the entomological literature and recorded observations on the German roach. This species, *Blattella germanica* (L.), was found to have two well defined breaking-points on each leg; one at the tibio-tarsal joint and the second between the trochanter and femur. Regeneration, as in all arthropods, occurred only at the time of ecdysis, normally at the first following the amputation, but even when a leg was removed immediately after eclosion the new growth was occasionally retarded through the succeeding stadium. Regenerated appendages frequently equalled the normal by the time adulthood was reached, except for the fact that renewed tarsi were always composed of only four subsegments in place of the usual five. Multiple fractures being repaired simultaneously appeared to proceed at approximately the same rate, but otherwise had no influence upon each other; at least, there was no perceptible decrease in rate.

In the last analysis, all cases of regeneration are merely phases of growth and should be treated as such. Any injury would be expected to affect the natural development of the individual and in turn its repair would be regulated to a large extent by the same factors which control the normal growth. Woodruff (1938, 1939) has discussed the normal development of this species from the standpoint of both mass and size. In each case increases, as compared with time, appeared to proceed at a decreasing rate of fairly constant proportions. If judged only by the stadia, these growth ratios were more uniform but such comparison disregarded the increased period of time required for the succeeding stadia and were thought not to

present the true relationship in developmental studies. The rates of increase, either of weight or of the various sclerotized parts of the body, were of such similar character as to suggest some fundamental governing factor in the genetic composition of the species for all growth phenomena.

The present experiments were conceived in an attempt to correlate the rate of growth of regenerating appendages with the normal progress of development for the animal.

PROCEDURE

The roaches used in the present tests were from an inbred stock which has been maintained for experimental purposes in our laboratory for several years. As needed, females bearing egg capsules were isolated from the stock culture and carefully observed to check the date and hour of eclosion. Newly emerged nymphs, following their allotted treatment, were separated into individual cages, supplied with abundant food and water, and housed in an incubator at a temperature of 27° to 30°C. The food, which previous tests had shown to be complete in a dietary sense, consisted of a finely ground mixture of 40% whole wheat flour, 40% dry skimmed milk, and 20% brewer's yeast. Every possible effort was made to subject all animals, whether control or experimental, to identical conditions.

Each clutch of young hatching from a capsule was divided into control and experimental groups, although not necessarily in the same proportion. As a rule, only about one-fourth were used as controls and permitted to develop without molestation. Test animals were subjected to forcible removal (appendotomy) of one or more legs as soon as possible after hatching, always within 24 hours. A leg to be disjoined was grasped firmly with forceps on the femur or tibia and steady tension exerted until separation occurred at the breaking point between the trochanter and femur. Test animals were subdivided as follows: members of one group lost only a single leg, the right metathoracic; in the second group, the right mesothoracic leg was removed in addition to the metathoracic, as above. This standard procedure not only simplified subsequent examinations, but permitted a comparison of the growth of regenerating limbs on one side of the body with that of the normal on the opposite side.

All animals were examined daily. At each ecdysis the individuals were removed to thin-walled glass containers which limited their movements and facilitated accurate measurement with an ocular micrometer. Tibiae on the regenerating and corresponding normal legs were measured at their greatest length, not including the terminal spines.

The data of this paper are from the measurements of roaches whose development was completed. Over one-half of the insects died from various causes before the adult stage was reached, and figures for these were discarded. Of an initial 400 nymphs only 170 matured, the death rate being generally higher among the experimental group and highest among those which underwent a double amputation. This may be explained at least in part by the impaired activity of roaches due to the

loss of legs. The powdered food, kept in small glass dishes, actually functioned as a trap for the young roaches who because of impaired traction were unable to scale the smooth sides of the container. Injured roaches frequently died also at the time of ecdysis. However, hereditary factors were of great importance in this connection, for all individuals from certain capsules appeared to be stronger regardless of the extent of the injury.

RESULTS

As frequently occurs in research problems, some unexpected events developed which had not appeared in the original prospectus of the experiments. Since these factors are of sufficient importance to warrant separate study, it becomes necessary to discuss the results under distinct headings.

TABLE I

MEASUREMENTS AND GROWTH RATIOS FOR NORMAL TIBIAE

Instar	Average Measurement in mm.	Difference	Ratio	Average Ratio
		MESOTHORACIC TIBIA		
1	0.55 ± 0.003	.....	.....	.....
2	0.72 ± 0.005	0.17 ± 0.006	1.308	.....
3	0.94 ± 0.008	0.22 ± 0.009	1.306	.....
4	1.23 ± 0.009	0.29 ± 0.012	1.308	.....
5	1.64 ± 0.016	0.41 ± 0.018	1.333	.....
6	2.15 ± 0.014	0.51 ± 0.021	1.311	.....
Adult	2.95 ± 0.019	0.80 ± 0.024	1.371	1.323
		METATHORACIC TIBIA		
1	0.82 ± 0.003	.....	.....	.....
2	1.11 ± 0.004	0.29 ± 0.005	1.356	.....
3	1.46 ± 0.007	0.35 ± 0.008	1.316	.....
4	1.90 ± 0.014	0.44 ± 0.016	1.302	.....
5	2.53 ± 0.015	0.63 ± 0.021	1.332	.....
6	3.33 ± 0.016	0.80 ± 0.021	1.316	.....
Adult	4.67 ± 0.024	1.34 ± 0.029	1.401	1.337

The earliest difficulty to become apparent was a variation in the time of appearance of the regenerating appendages. In the normal course of events, miniature legs appeared at the ecdysis immediately following the appendotomy, namely, the first in this series of tests. Approximately 18% of the test animals, however, showed no evidence of a new leg until the second molt. Naturally the growth of an appendage during this first period in one insect cannot be compared with a non-existent value in another. Consequently, it will be necessary to allot the experimental animals into two divisions according to the time of first appearance of the regenerating appendage.

A second problem which further differentiated the experimental animals was that of the number of molts undergone in completing their development. German roaches normally molt six times. Sixty-nine per cent of the individuals in these tests followed this precedent, but the remaining 31% required an additional molt before attaining adulthood. That this was made necessary by the mutilation inflicted is attested by the fact that a greater portion of those undergoing a double injury molted seven times than was true where only a single amputation was involved. This phase of the problem has been dealt with in a separate

TABLE II

INDEPENDENT REGENERATION OF METATHORACIC TIBIAE FOR ROACHES WHICH MOLTED SIX TIMES

LEFT, UNINJURED TIBIA			RIGHT, REGENERATING TIBIA		
Instar	Average Measurement in mm.	Ratio	Instar	Average Measurement in mm.	Ratio
REGENERATION INITIATED IN SECOND INSTAR (26)					
1	0.86 ± 0.006	.....	1	.....	.....
2	1.13 ± 0.005	1.31	2	0.86 ± 0.008	.....
3	1.48 ± 0.009	1.31	3	1.30 ± 0.015	1.51
4	1.87 ± 0.016	1.26	4	1.80 ± 0.017	1.38
5	2.46 ± 0.019	1.32	5	2.41 ± 0.018	1.34
6	3.22 ± 0.022	1.31	6	3.20 ± 0.025	1.33
Adult	4.59 ± 0.034	1.43	Adult	4.59 ± 0.037	1.43
REGENERATION INITIATED IN THIRD INSTAR (6)					
1	0.80 ± 0.006	.....	1	.....	.....
2	1.11 ± 0.013	1.39	2	.....	.....
3	1.44 ± 0.013	1.30	3	1.16 ± 0.025	.....
4	1.82 ± 0.076	1.26	4	1.65 ± 0.027	1.42
5	2.47 ± 0.040	1.36	5	2.43 ± 0.010	1.47
6	3.30 ± 0.037	1.34	6	3.28 ± 0.025	1.41
Adult	4.68 ± 0.072	1.42	Adult	4.63 ± 0.084	1.41

paper (Seamans and Woodruff, 1939), and will be discussed here only as it pertains to the growth of regenerating appendages.

Normal growth. Normal growth ratios have been calculated and discussed for this species by the senior author (Woodruff, 1939), involving the measurements of the head capsule and pronotum as well as the mesothoracic and metathoracic tibiae. The summaries for the latter two are repeated here in Table I to serve as standards with which the growth of regenerating appendages may be compared. The average dimensions for 56 roaches in each instar are given along with their probable errors. The differences between succeeding instars and the

ratio of each to its predecessor are also listed. A mean progression ratio has been calculated for each tibia.

Regenerative growth, six molt type. These data can best be presented in the form of tables, most of which are to a large extent self-explanatory. In each table the average measurement in millimeters is given for the group in successive stages, with the corresponding growth ratios. For

TABLE III

DOUBLE REGENERATION OF TIBIAE FOR ROACHES WHICH MOLTED SIX TIMES

LEFT, UNINJURED TIBIA			RIGHT, REGENERATING TIBIA		
Instar	Average Measurement in mm.	Ratio	Instar	Average Measurement in mm.	Ratio
MESOTHORACIC TIBIA, REGENERATION INITIATED IN SECOND INSTAR (42)					
1	0.60 ± 0.004	.....	1	.....	.....
2	0.75 ± 0.006	1.25	2	0.62 ± 0 006	.....
3	1.00 ± 0.007	1.33	3	0.92 ± 0.010	1.48
4	1.29 ± 0.010	1.29	4	1.26 ± 0.010	1.37
5	1.71 ± 0.014	1.32	5	1.69 ± 0.014	1.34
6	2.21 ± 0.012	1.29	6	2.21 ± 0.012	1.31
Adult	3.05 ± 0.017	1.38	Adult	3.05 ± 0.017	1.38
METATHORACIC TIBIA, REGENERATION INITIATED IN SECOND INSTAR (42)					
1	0.88 ± 0.004	.....	1	.....	.....
2	1.13 ± 0.004	1.29	2	0.87 ± 0.031	.....
3	1.51 ± 0.008	1.33	3	1.38 ± 0.011	1.59
4	1.94 ± 0.014	1.29	4	1.86 ± 0.012	1.35
5	2.60 ± 0.016	1.34	5	2.53 ± 0.021	1.36
6	3.35 ± 0.019	1.29	6	3.33 ± 0.020	1.32
Adult	4.72 ± 0.024	1.41	Adult	4.71 ± 0.025	1.41
METATHORACIC TIBIA, REGENERATION INITIATED IN THIRD INSTAR (5)					
1	0.84 ± 0.043	.....	1	.....	.....
2	1.14 ± 0.004	1.36	2	.....	.....
3	1.46 ± 0.028	1.28	3	1.21 ± 0.012	.....
4	1.94 ± 0.028	1.33	4	1.92 ± 0.021	1.59
5	2.57 ± 0.028	1.32	5	2.54 ± 0.041	1.32
6	3.31 ± 0.033	1.29	6	3.30 ± 0.038	1.30
Adult	4.78 ± 0.095	1.44	Adult	4.78 ± 0.095	1.45

the sake of comparison, values of the left uninjured appendage are included. As a matter of fact, the corresponding data for the uninjured appendages are perhaps even better checks than those of the normal animals in Table I, inasmuch as any deleterious reaction resulting from the injury and being reflected in the growth of the new appendage would probably also show in the leg of the opposite side of the body.

Consequently this comparison will be made throughout most of the paper.

In Table II are shown the data for 32 roaches from which only the right metathoracic legs were removed and which molted the usual six times. In 26 of these the new leg appeared after the first molt, while in the other six any external evidence of regeneration was delayed until the second. Attention should be directed to the fact that the regenerated leg at its definitive size virtually equals that of the left uninjured leg; in some of the later tables the regenerative growth equals or even excels the normal. As a matter of fact, equality is practically reached after only one or two molts and during later periods the two simply keep pace in their progress. This, of course, indicates a much larger rate of growth for the regenerating leg during those first few stadia than is true of the normal leg. Naturally also an even greater acceleration is

TABLE IV

INDEPENDENT REGENERATION OF METATHORACIC TIBIAE FOR ROACHES WHICH MOLTED SEVEN TIMES; REGENERATION INITIATED IN SECOND INSTAR (7)*

LEFT, UNINJURED TIBIA			RIGHT, REGENERATING TIBIA		
Instar	Average Measurement in mm.	Ratio	Instar	Average Measurement in mm.	Ratio
1	0.83 ± 0.008	.....	1	.....	.....
2	1.11 ± 0.007	1.34	2	0.85 ± 0.016	.....
3	1.46 ± 0.008	1.32	3	1.27 ± 0.025	1.49
4	1.79 ± 0.018	1.23	4	1.71 ± 0.026	1.35
5	2.26 ± 0.028	1.26	5	2.18 ± 0.028	1.27
6	2.81 ± 0.018	1.24	6	2.73 ± 0.035	1.25
7	3.55 ± 0.031	1.26	7	3.54 ± 0.051	1.30
Adult	5.00 ± 0.065	1.41	Adult	4.94 ± 0.061	1.39

*Only two individuals of this series had the regeneration initiate in the third instar. Average values for this number were not considered of such significance to warrant tabulation.

characteristic of the regenerating appendage when its initial appearance is delayed until the third stadium. This condition is not shown so typically here as in other of the tables since the first growth ratio is abnormally smaller than the second.

Of those roaches which had both the mesothoracic and metathoracic legs removed, 47 molted six times and the comparative data for these are shown in Table III. In 42 individuals of this series the regeneration of both legs was started in the next succeeding instar and measurements are summarized for the mesothoracic as well as the metathoracic tibia. The metathoracic leg of five roaches did not appear until after the second molt. Discrepancies in the origin of the related mesothoracic tibiae make it undesirable to include them in the table. Again it is striking that the early growth of the regenerating parts is the most rapid and merely keeps pace with that of the uninjured tibiae during

the later stadia. The rates of growth for both the regenerating and normal tibiae of the mesothoracic and metathoracic legs are amazingly similar. The total growth of the latter, of course, is materially greater and yet the controlling factors of the two rates appear to be the same.

TABLE V

DOUBLE REGENERATION OF TIBIAE FOR ROACHES WHICH MOLTED SEVEN TIMES

LEFT, UNINJURED TIBIA			RIGHT, REGENERATING TIBIA		
Instar	Average Measurement in mm.	Ratio	Instar	Average Measurement in mm.	Ratio
MESOTHORACIC TIBIA, REGENERATION INITIATED IN SECOND INSTAR (19)					
1	0.60 ± 0.006	.....	1	.....	.....
2	0.74 ± 0.008	1.23	2	0.61 ± 0.013	.....
3	0.95 ± 0.012	1.28	3	0.86 ± 0.014	1.41
4	1.17 ± 0.011	1.23	4	1.15 ± 0.012	1.34
5	1.50 ± 0.018	1.28	5	1.49 ± 0.020	1.29
6	1.89 ± 0.025	1.26	6	1.87 ± 0.031	1.25
7	2.41 ± 0.032	1.28	7	2.39 ± 0.036	1.28
Adult	3.21 ± 0.031	1.33	Adult	3.17 ± 0.038	1.33
METATHORACIC TIBIA, REGENERATION INITIATED IN SECOND INSTAR (19)					
1	0.85 ± 0.007	.....	1	.....	.....
2	1.14 ± 0.012	1.34	2	0.87 ± 0.013	.....
3	1.45 ± 0.011	1.27	3	1.28 ± 0.013	1.47
4	1.79 ± 0.020	1.23	4	1.69 ± 0.028	1.32
5	2.27 ± 0.023	1.27	5	2.20 ± 0.025	1.30
6	2.84 ± 0.032	1.25	6	2.80 ± 0.030	1.27
7	3.60 ± 0.031	1.27	7	3.58 ± 0.028	1.28
Adult	5.02 ± 0.034	1.40	Adult	5.02 ± 0.038	1.40
METATHORACIC TIBIA, REGENERATION INITIATED IN THIRD INSTAR (7)					
1	0.84 ± 0.011	.....	1	.....	.....
2	1.10 ± 0.008	1.31	2	.....	.....
3	1.43 ± 0.011	1.30	3	1.15 ± 0.026	.....
4	1.75 ± 0.025	1.22	4	1.67 ± 0.023	1.45
5	2.21 ± 0.029	1.26	5	2.14 ± 0.026	1.28
6	2.71 ± 0.032	1.23	6	2.69 ± 0.037	1.26
7	3.44 ± 0.038	1.27	7	3.42 ± 0.042	1.27
Adult	4.69 ± 0.061	1.36	Adult	4.69 ± 0.062	1.37

Regenerative growth, seven molt type. A total of 35 specimens required seven molts for their development, nine receiving a single and 26 a double injury. Of the former, the renewed appendages appeared after the first molt in seven and the data for these are shown in Table IV.

The growth ratios of either the regenerating or uninjured tibiae are not particularly different from those of the corresponding group undergoing six molts, except for a slight diminution throughout. Here, as before, the regenerating leg soon overtakes the normal and keeps pace during the later stadia. In only two individuals of this series was the regeneration retarded until the second molt. Average values for this number were not considered of such significance to warrant discussion. However, it may be said that the behavior of these was in general accord with that of the other members of the group.

Data for the 26 roaches which underwent a double amputation and molted seven times are shown in Table V. In seven of these the regenerating metathoracic leg did not appear until after the second molt; these are separated from the nineteen in which the new growth originated at the first opportunity. The growth values for each of these groups represent a more even rate than has been encountered previously. Perhaps somewhat smaller, in keeping with the added growth period, the values of the growth rates are surprisingly uniform throughout development except for the usual acceleration at the last molt in all cases and at the time of the first formation of the regenerating appendages.

DISCUSSION

In a previous paper Woodruff (1939) has attempted to show that the growth of sclerotized parts of the insect's body tends to conform to the equation

$$\log L = a + bt + c \log t$$

where L = any linear measurement; t = time; and a, b, and c are constants of progression. Of course, t refers not simply to the successive stadia but to the actual period of time consumed in the discontinuous growth as possible in insects only in conjunction with the process of molting. Stated simply, this means that the rate of increase tends to decrease more or less constantly with time.

While not outwardly apparent because the time element is overlooked in calculations made on the basis of stadia alone, the growth ratios of the normal tibiae as presented here roughly follow the above statement. An increasing length of time was found necessary for the succeeding stadia, ranging from an average of 5.8 days for the first to 13.1 days for the last. This means that the apparently greater ratio of approximately 1.4 for the last stage of growth is actually proportionally less than the others when judged on a time-growth basis. Since growth ratios are universally calculated on the basis of stadia only, the reader is forced into mental orientation to interpret the true nature of the progression.

True also, the growth of the uninjured appendages which are used as standards in each group of experiments cannot be classed strictly as normal, for they occurred on the bodies of animals which had been injured by the removal of one or more legs. Yet the rate of increase for these controls usually compares favorably with that of the animals normal in every respect, as shown in Table I. Since differences, even if

significant, are slight the growth rates of the corresponding uninjured legs will be used as checks in each case.

Unpredicted factors such as the delayed appearance of the regenerating appendage and the occurrence of an additional molt have complicated the consideration of this problem beyond the limits of single factor analysis. In 17.5% of the experimental animals the new leg did not appear until after the lapse of one stadium; 30.7% required seven molts during the developmental period. Quite naturally, the rates of growth for these various groups are not comparable and must be considered on different bases.

With very few exceptions the regenerating appendages equal, and in the cases of the seven molt type of development often excel the normal in size by the time the insect becomes an adult. As a matter of fact, the speed with which equality is reached is sometimes amazing. Naturally, under these conditions one would expect a somewhat larger progression rate throughout the entire development Actually, the most rapid increase occurs at the molts immediately following the amputation or the incipience of growth of the regenerating part. The result is that the regenerating and normal legs are practically equal after only a very few molts; sometimes only one and practically never more than three are required before the two legs appear as identical. Then during later stadia the two simply keep pace, within the limits of variability. This condition holds even in those instances where the appearance of a new leg is delayed until after the lapse of a stadium. Consequently, the largest rate of growth occurs in those roaches in which the regeneration is not initiated until the third stadium. However, it must be remembered that the growth ratios as calculated here do not depict the entire extent of the acceleration, since the initial measurement is usually larger than that for the normal legs and this fact is not reflected in the rate. This is especially true when the appearance of a leg has been delayed through one stadium and at the beginning is intermediate in size between that of the normal leg at the second and third molts, thus eliminating entirely the first period of growth. The early growth of regenerating parts then represents an enormous acceleration over the average condition and a rate proportionally greater than the normal for the same period. This is in keeping, although an exaggeration, with the constantly decreasing rate so characteristic of the development of normal tissues in this species where the most rapid increase is always made in early life. Przibram (1917) obtained somewhat similar results when he compared the growth of regenerating appendages in thirteen *Sphodromantis bioculata* Burm., with that of the normal and found an initially accelerated growth to diminish in velocity with age.

This behavior obtains for both the mesothoracic and metathoracic legs, the two with minor variations being mere duplicates of each other when considered separately. An examination of Tables III and V will show the similarity between the growth rates of the two tibiae. Naturally, the values for average measurements of the mesothoracic leg are considerably smaller, but the progression factors of the two are approximately the same throughout development for both the six and seven molt groups. Since the contributing elements which influence

normal growth produce body structures at a constantly decreasing rate, and since the rates for regenerating appendages are similar to or identical with this, it is apparent that we may be dealing with only a single set of factors which manifest themselves whenever growth is involved. Undoubtedly, the answer is to be found in the controlling genes of the species.

Unwittingly, one might assume that a more extensive injury would result in a slower rate of repair. While this may be true to some extent and particularly for extreme mutilation, it cannot be detected in the growth of roaches suffering a double injury, i. e., when both a mesothoracic and metathoracic leg are removed simultaneously. The progression rates for the metathoracic tibia, whether developing alone or in conjunction with a mesothoracic tibia, are not noticeably different if the corresponding data of Tables II and III or IV and V are compared. The same general conditions seem to prevail for the two cases in point. Apparently, this compound injury is not great enough to retard seriously the usual speed of repair. Zeleny (1905) and Bennazzi (1929) have implied a direct relationship between the size of the lost part or the extent of the injury and the rate of regeneration. Obviously this generalization must have its limits. Any great stimulating effect in the regeneration of compound injuries in the roach escaped notice by the present authors.

Actually the experimental animals appear to be little affected by the injury of amputation or the subsequent necessity of regenerating a new leg or legs. Growth in general is not noticeably different from that of the perfectly normal animal and the injuries are soon repaired. It is difficult to understand how an injury which otherwise is of so little influence can produce such a profound change as the injection of an extra stadium in the developmental period. Nevertheless, this seems to be the case for, as has been pointed out in a previous paper (Seamans and Woodruff, 1939), only the experimental animals exhibited this phenomenon, and in these its occurrence was more common among those which suffered a double amputation. In the growth of uninjured structures the presence of this added stadium results in a lessened rate and a somewhat larger total increase, but the nature of the progression in general is about the same as for the usual number of molts. Again, the early increases are the greatest and the ratios then proceed at a lessened rate. About the same proportional difference also obtains here between the rates of regenerating appendages and of the normal as was found for the six molt type of development. The added stadium is not merely appended to the six normal periods of growth, but its influence is manifest in the increases produced during the early ecdyses and continues throughout the remaining life. The progression factors in the seven molt development (compare Tables III and V) appear to be somewhat more uniform than elsewhere. However, this fairly constant rate when correlated with time, which as before is increasing sizeably for each succeeding stadium, becomes the constantly decreasing rate of normal growth.

SUMMARY

Regenerating appendages, as studied in *Blattella germanica* (L.) through the measurements of tibiae, appear to grow at a rate very similar to that of normal appendages, except for a considerable acceleration during the early stadia. Legs were removed shortly after eclosion by disarticulation between the trochanter and femur. Most often the regenerating appendages appeared at the molt immediately following the amputation, but occasionally were delayed until the second ecdysis. In either case, the early growth was most rapid, and usually within one or two stadia the regenerating appendage had approximately equalled the corresponding normal leg. After equality was reached, the two tibiae merely kept step during later life. When the incipience of an amputated leg was delayed until the second molt, the acceleration was even more pronounced than before, but again equality was soon attained. Double injury in the form of the amputation of two legs did not alter the rate of repair noticeably. The incidence of an extra molt was increased by the injury of amputation and the growth rate altered accordingly. However, the progression factors in the seven molt type of development followed the normal trend and decreased in the same way, even though smaller in value. Roaches undergoing an extra molt attained a slightly larger size than was usual. The similarity between the normal growth rates and those for the regenerating appendages indicates a single set of controlling factors which manifest themselves wherever growth is involved.

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PATTERNS OF SURVIVAL, AN ANATOMY OF LIFE, by JOHN HOGDON BRADLEY. Pages 1–223 (no illustrations), 1938; size 6 x 8.5 inches. THE MACMILLAN CO., 60 Fifth Ave., New York City. Price, $2.25.

The author is a geologist who graduated from Harvard with an A.B., *magnum cum laude*, and later took a Ph.D. at Chicago University with the same label of excellence. He is a top flight writer who has furnished articles for such reviews of distinction as *The Yale Review*, *The American Mercury*, *The Forum*, *The American Scholar* and *Harper's Magazine*.

The volume is an excellent popular review from an evolutionary point of view of life in terms of the latest biological thought. Apparently the work is not intended for the scientific student as it is neither indexed nor does it have a bibliography nor a detailed table of contents. To the scientist reader it is even annoying at times because the author frequently uses brilliant suggestive or explanatory ideas which apparently are not always original but which cannot be traced back to an earlier writer for a fuller explanation.

The popular form of the exposition is such through a rich and brilliant use of figures of speech and a sufficient inweaving of the emotional to keep the reader awake and even on his toes for fear he will miss some of the more thrilling incidents in this panaroma of life. From the view of cold logic the author has overwritten his subject.

The contents run as follows:

"The Question and the Quest." After pointing out the conflict in biological philosophy between mechanism and vitalism the author suggests, "The student of earth history sees in retrospect what could never have been foretold. Life was a new experiment under the sun. A bit of jelly quivering to the surge of the sea might scarcely have been suspected of power to alter the earth. . . . If there is any meaning . . . in the restless drive of life, a billion years of living should contain it. To search those years for that meaning will be the object of this book."

Chapter I. "In the Beginning:" a discussion of Pre-Cambrian conditions. Chapter II. "The Other Side of Progress:" sedentary life. III. "The Mechanics of Success:" evolution and locomotion. IV. "The House Divided:" biological conflicts, plant life, herbivores, carnivores, food chains, over population. "The house of life divided against itself stands only because it is divided." V. "Life Without Struggle:" the degeneracy of parasitism, with an interesting review of human social parasites. VI. "The Way of Love:" bisexual reproduction, maternal care, family life, co-operation. VII. "The Broader Brotherhoods of Flesh:" life at unicellular level, at coelenterate and colonial level, at the level of herd life and at social levels. VIII. "The Tragic Rhythm:" death in too high specialization, other evolutionary trends, life only possible hand in hand with death and extinction. IX. "The Business of Growing Up:" various evolutionary "improvements" and their values. X. "Is Man an Absurdity? When Nature evolved modern man, she improved only the brain, the larynx and the hands and allowed all other essential gadgets to degenerate. . . . Man is an appalling hodge-podge of second-hand odds and ends," but "the gravest dangers for man as a species lie less in the crumbling beast than in the bungling god." IX. "The Embarrassment of Being Different. . . . No other creature has faced sterner problems with fewer guides to workable solutions, but solutions may come through man's unique feature of discontent with discontent. . . . Self-directed evolution so far as he knows, is an adventure without precedent in a billion years."

The exposition is full of minor errors of fact, many of which could have been caught by competent readers. We quote, p. 152: "Drone bees are so specialized as gigolos that they are incapable of any other pursuit. They are unable to gather pollen (*should be* nectar) because their tongues are too short. They are unable to work on the hive because they have no wax glands (*should be* because of their nervous mechanism). They are unable to fight because they have no stings (*again* because of the nervous control of behavior). They would rather starve than collect food for themselves" (*anthropomorphic expression*). This careless writing disregards all previous careful observations and precise experimentation by scientists in general.

The volume is so full of highly suggestive ideas (though too frequently based on highly selected evidence) that we recommend it in spite of its numerous minor slips. It is interesting and actually absorbing page after page.—C. H. K.

LIFE HISTORIES OF AGRION AEQUABILE AND AGRION MACULATUM

(Agriidae: Odonata)

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While the mature nymphs of *Agrion aequabile* Say and *Agrion maculatum* Beauv. are readily distinguishable in the field, the species are easily confused in earlier instars, particularly where both occur in the same stream. The distributional ranges of the two forms overlap in the Canadian and Transitional faunal zones; thence, *aequabile* is found northward to the Hudson Bay Slope, *maculatum* southward to Florida and Texas. In Ontario, as elsewhere over their range, the nymphs are distinctly local in occurrence, being nowhere plentiful, and restricted for the most part to slow creeks and quiet areas of running streams. The distribution of each species in a stream appears to be determined by rate of flow, depth of water, type of vegetation and other factors.

With a view to rendering the species more distinct in immature stages, the life histories and ecology of *A. aequabile* and *A. maculatum* have been studied over a period of two years. In this connection mention must be made of the work of Nevin (1930) who succeeded in rearing *maculatum* to the fifth instar. He also obtained data on six later stages by the collection of older nymphs, but since the number of individuals available for statistical treatment was small, the number of instars arrived at was incomplete.

Rearing Methods. Freshly deposited eggs of both species were obtained from streams near Cache Lake, Algonquin Park, Ontario, and there incubated in the laboratory. Newly hatched nymphs were transferred to individual containers, and detailed records were kept as the experiment progressed. During the latter part of the work, the rearing dishes were suspended on aluminum trays in a water bath at 18.8–19° C. Water flowing continuously through the tank, surrounded each dish to within 6 mm. of the top. Pond- or lake-water in the individual containers was aerated with commercial compressed air through fine glass jets inserted at suitable intervals into rubber tubing carrying the air supply. The volume of air bubbling through

TABLE I

AVERAGE AND RANGE OF DURATION IN DAYS OF SUCCESSIVE INSTARS IN REARED SERIES OF *Agrion aequabile* AND *Agrion maculatum*. Figures in brackets indicate number of individuals, regardless of sex, for which exact duration is known. (Av.—average; R.—range.)

SPECIES		INSTAR										
A. aequabile		II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Hatching July 19: First exuviae August 4–13.....	Av....	(12) 11.4	(14) 13.7	(19) 15.1	(17) 18.4	(17) 23.7	(16) 30.3	(10) 42.1	(1)	.....	.....	Total average time instars II–IX inclusive, 190.7 days.
	R.....	7–15	8–29	9–27	14–25	18–31	17.84	21.66	36(died)	.....	.....	
A. maculatum Hatching July 19: First exuviae August 1–7.....	Av....	(2) 10	(8) 13.6	(9) 13.4	(9) 15.8	(9) 20.1	(8) 20.2	(8) 23.8	(3) 24.3	(2) 45	(1)	(1) .....
	R.....	8–12	8–24	11–17	13–25	15–36	14–26	14–36	19–29	39–51	24	63 (died very near emergence) Total average time, instars II–IX inclusive, 141.2 days. Total average time, instars II–XII inclusive, 273.2 days.

each container per unit time was regulated by screw pinchcocks, and glass microscope slides protected the animals from dust.

The nymphs were found to feed most readily on fine lake-plankton during the summer, and on *Enchytraeus* worms and *Daphnia* during the winter.

Collected material. Statistical data afforded by the reared material were augmented by summer and winter collections of nymphs of both species in the streams near Cache Lake. Various ecological observations on temperature, depth and speed of water, vegetation, substratum and pH were also recorded but will not be considered here. A number of immature nymphs taken in collections were kept for a time in stream cages, and their consecutive exuviae were collected and measured as a check on the growth of the reared material.

LIFE HISTORIES

Oviposition. In Ontario the eggs of *A. aequabile* and *A. maculatum* are most frequently deposited in leaves of the bur-reed *Sparganium americanum.* Each species oviposits in a characteristic manner. The eggs of *maculatum* are deposited just beneath the surface of the water, on leaves floating horizontally in a brisk current. Those of *aequabile* are inserted in submerged parts of the plant, the female descending a foot or more below the surface in quieter parts of the streams, sometimes remaining there for a period of half an hour or more.

Incubation and Hatching. The eggs of both species appear to develop equally well in still or in moving water. The incubation period was found to vary from 26 to 29 days for *maculatum* and from 18 to 29 days for *aequabile.* 27.2° C. was the highest recorded temperature to which any of the eggs were subjected. Unhatched eggs of either species are hard to obtain after the end of July, and it is reasonably certain that none winter over.

The process of hatching was observed in detail for *maculatum* only, but appears to be identical in both species. The egg capsule most often ruptures during the night or early morning, and emergence occurs after varying periods of time (9 hours after rupture on one occasion). During this time (Plate I) a membranous vesicle of doubtful identity appears through the crack at the micropylar end of the egg, and becomes greatly distended by the pressure of fluid within. The pronymph moves slowly up into the vesicle until the head, exerting sufficient pressure against the membrane, ruptures the vesicle and propels the creature out of the capsule, as far as the gills. At this point the pronymphal skin is shed by a series of forward waves of contraction, and in a moment or two the nymph is fully active.

Number of Instars and Duration of Nymphal Life. The number of nymphal instars was found to be eleven to twelve in the case of *maculatum,* twelve to thirteen in the case of *aequabile,* twelve, however, being the most common number in each species. In general, duration of stadium tends to increase with successive instars (Table 1).

If the total growth of various organs from any one stage in development be plotted against total time elapsed from that stage, the resulting curves indicate that in *aequabile*, the general rate of growth, initially more rapid than that of *maculatum*, decreases gradually as development proceeds. In *maculatum*, the rate of growth more or less increases toward maturity. Females of both species appear to require longer to mature than the males. Figs. 1 and 2 represent partial growth curves

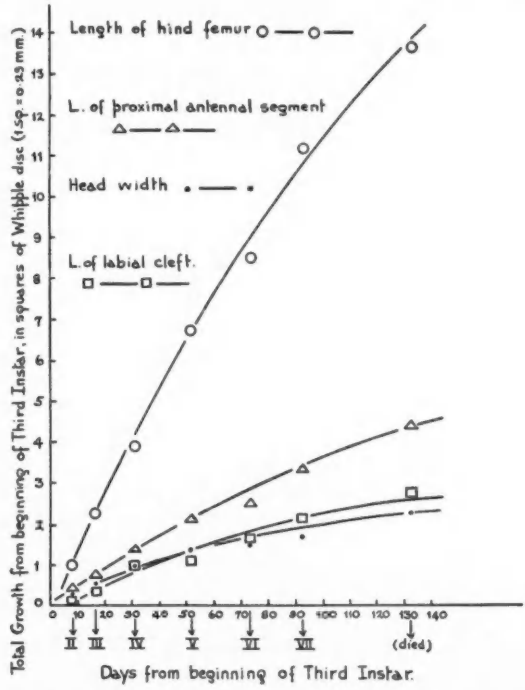

Fig. 1. Partial growth curves for four body-parts of a reared nymph of *A. aequabile.*

for a reared individual of each species. Those for *maculatum* were the most complete secured during the rearing experiments, since nymphal mortality was extremely high in early stages and toward maturity, particularly at times of moulting. But two reared nymphs (♂♂) of this species reached the final instar, and neither transformed successfully. *A. aequabile* is still more difficult to rear under laboratory conditions. Nearly mature nymphs of either species, brought from stream to laboratory, will, however, transform quite successfully. Laboratory conditions, rendered however "natural," appear to lack some important

requisite for normal moulting and transformation, since by far the greatest mortality in reared series occurred prior to or just after ecdysis.

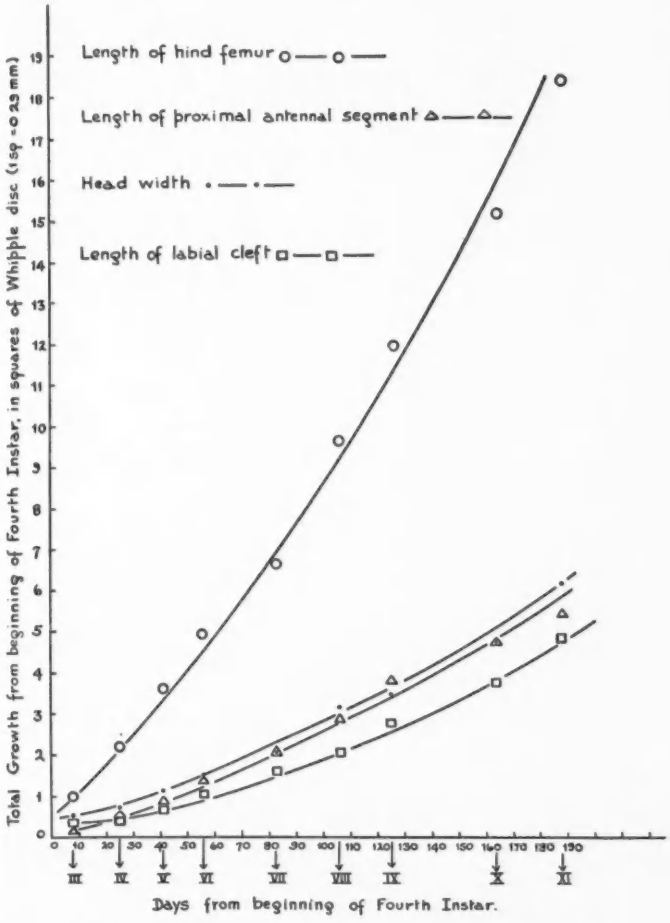

Fig. 2. Partial growth curves for four body-parts of a reared numph of *A. maculatum*.

It is estimated that *A. maculatum* normally completes development in one year or less, where some growth occurs during the winter. Time-data for *A. aequabile* are incomplete in the final stages but indicate that nymphal life is of two or more years' duration.

DESCRIPTION OF NYMPHAL INSTARS

Method of separation of the species. A preliminary separation of collected material into instars regardless of species, was made with the aid of measurements taken from each individual. Morphological characters chosen for analysis included head width just behind the eyes and

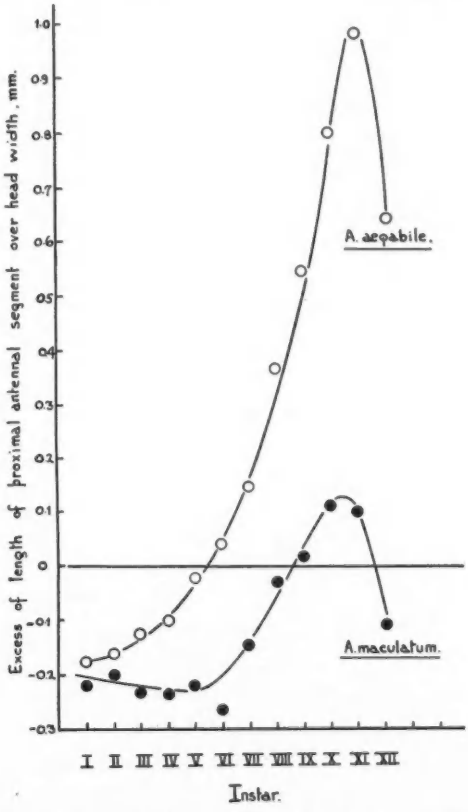

Fig. 3. Comparative magnitudes of length of proximal segment of antenna and head width in *A. aequabile* and *A. maculatum* during development.

lengths of proximal segment of antenna, whole antenna, hind femur, dorsal and lateral gills, front tarsal claws, mental cleft of the labium, and metathoracic wing pad. Each nymph was also examined for the number of segments in the antenna and for the presence or absence of gonapophyses. In separating the species the first two characters have

proven most useful. The length of the proximal antennal segment in *maculatum* is for the most part less than the maximal head width, while in *aequabile*, the proximal segment rapidly approaches the magnitude of the head width in early instars, and exceeds it thereafter. Fig. 3 shows these relationships based on the average measurements given in Tables II and III.

Method of separation of Instars. Following segregation of collected material into species, frequency histograms covering the last six instars were constructed for each species on the basis of three sets of measurements. The three characters used in this analysis have been found to show least variability in any one instar. Measurements of exuviae, with the possible exception of head width in some cases, appear to be entirely comparable with those of corresponding nymphs. Probable instar-limits in the histograms were fixed with reference to exuviae of living material; a certain amount of overlapping is found from instar to instar, depending on the character chosen.

Data useful in description of instars I–VII were obtained from all available exuviae and nymphs of the reared series.

Tables accompanying the description of instars are based on a census of all available material reared or collected over a period of two years, and data are expressed to the nearest hundredth of a millimetre. Measurements of mutilated or regenerating structures are omitted from the records. Collected material was examined with a squared eyepiece in conjunction with 10X ocular and 1.7X objective Spencer binocular attachments. For reared material a 34X objective was substituted.

Agrion maculatum Beauv.

DESCRIPTION OF INSTARS

(See Table II)

First instar. (Plate I (h)). Nymph grayish in color, about 2 mm. long, inclusive of gills. Antennae with three segments, the first two pigmented, the third pale. Femora with single distal cross-band of pigment, tarsi one-segmented. Tenth abdominal segment dark, gills of equal length in most individuals.

Mouthparts. The characteristic single movable hook of the labial palpus is present from the first instar. Two of the usual three immovable hooks are present, each with one large and one small seta at its base. Median lobe of mentum slightly cleft. Left mandible with much stronger molar surface than right. Galeolacinia of maxilla with four hooks, palpus with three or four lateral setae.

Second instar. Antennae four-segmented, the first segment longer than the others, distal parts of segments one and two pigmented. Tarsi one-segmented. Tenth abdominal segment no longer dark, dorsal gill slightly shorter than the laterals.

Mouthparts. Palpus bearing two immovable hooks, each with a single seta at the base. Galeolacinia of maxilla with five hooks.

Third instar. Antennae five-segmented, the first two segments pigmented distally. Femora with three pigmented cross-bands, the distal one darkest and broadest, the proximals paler and narrower.

TABLE II

Agrion maculatum Beauv.

EXTERNAL MEASUREMENTS OF NYMPHAL INSTARS, AVERAGES AND RANGES, mm.

Figures in brackets represent number of individuals upon which each measurement is based.

(Av.—average; R.—range.)

CHARACTER		INSTAR											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Head width	Av.	(5) .39	(6) .43	(11) .51	(11) .59	(12) .66	(10) .92	(10) 1.02	(47) 1.20	(28) 1.44	(74) 1.83	(89) 2.30	(11) 2.95
	R.	.38–.41	.43–.46	.49–.55	.55–.67	.59–.81	.83–1.07	.87–1.13	1.03–1.37	1.31–1.65	1.60–2.05	1.99–2.62	2.56–3.13
Length prox. seg. antenna	Av.	(5) .16	(7) .22	(12) .27	(12) .35	(12) .43	(11) .65	(10) .87	(47) 1.17	(28) 1.46	(75) 1.94	(88) 2.40	(10) 2.84
	R.	.14–.17	.20–.26	.26–.35	.30–.46	.38–.61	.51–.72	.75–.99	1.08–1.37	1.37–1.71	1.60–2.28	2.11–2.62	2.68–3.02
Length antenna	Av.	(5) .43	(7) .55	(11) .69	(12) .87	(12) 1.04	(11) 1.45	(10) 1.83	(44) 2.33	(27) 2.84	(73) 3.63	(82) 4.36	(9) 5.02
	R.	.40–.46	.52–.61	.63–.87	.78–1.07	.94–1.33	1.19–1.64	1.59–2.00	2.11–2.56	2.56–3.19	3.19–4.22	3.88–4.84	4.73–5.47
Length lateral gill	Av.	(5) .51	(7) .71	(11) 1.04	(12) 1.46	(12) 1.92	(10) 2.93	(9) 4.19					
	R.	.49–.55	.67–.78	.88–1.36	1.15–1.89	1.46–2.70	2.05–3.51	3.28–4.56					
Length dorsal gill	Av.	(5) .50	(5) .69	(6) 1.00	(6) 1.38	(7) 1.72	(7) 2.66	(7) 3.58					
	R.	.43–.52	.61–.84	.85–1.07	1.05–1.74	1.30–2.35	1.88–3.13	2.84–3.89					
Length hind femur	Av.	(5) .45	(7) .65	(12) .84	(12) 1.12	(12) 1.35	(11) 2.02	(10) 2.86	(46) 3.46	(27) 4.15	(73) 5.29	(89) 6.33	(10) 7.30
	R.	.43–.46	.61–.70	.80–1.10	1.00–1.51	1.16–1.97	1.60–2.49	2.32–3.13	2.91–3.82	3.70–4.67	4.45–6.10	5.36–7.47	7.01–7.75
Length front tarsal claw	Av.	(5) .10	(7) .10	(11) .12	(12) .14	(12) .16	(11) .19	(10) .23	(43) .23	(25) .27	(72) .32	(79) .36	(10) .42
	R.		.09–.12	.12–.14	.12–.15	.14–.20	.17–.23	.20–.26	.17–.28	.23–.28	.17–.40	.28–.46	.40–.51
Length labial cleft	Av.	(3) .03	(6) .07	(12) .12	(11) .19	(10) .29	(8) .40	(10) .60	(46) .73	(28) .95	(72) 1.28	(89) 1.61	(10) 1.93
	R.		.06–.09	.11–.17	.14–.26	.26–.35	.35–.43	.46–.68	.68–.85	.85–1.14	1.02–1.54	1.31–1.82	1.77–2.05
Length metathoracic wingpad	Av.								(33) .75	(16) 1.00	(56) 1.70	(56) 2.92	(3) 5.79
	R.								.51–.97	.80–1.31	1.31–2.68	2.56–3.25	5.41–6.04

Tarsi two-segmented, the proximal segment about one-third as long as the distal. Four small pigmented areas are apparent immediately in front of the meso- and metathoracic coxae in the region of the subse-

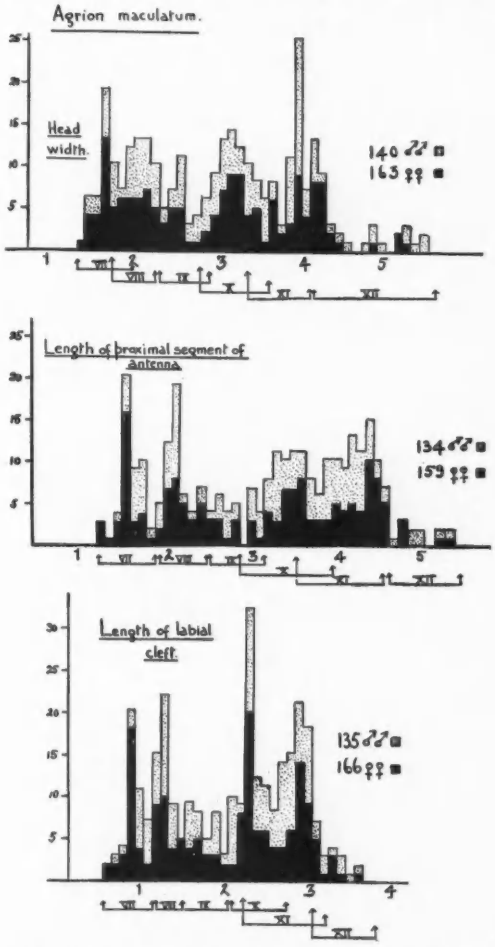

Fig. 4. Frequency histograms for three nymphal characters of *A. maculatum*, instars VI–XII. Ordinates represent frequency of occurrence, abscissae, observed magnitudes in squares of Whipple disc (1 square—0.57 mm.).

quently developing wing-pads. Gills deeply pigmented distally. A profile view of the exuvial abdomen now reveals a row of mid-dorsal tubercles, one near the posterior margin of each tergum. At about the

eighth instar these begin to undergo retrogression, and are not apparent in the last few instars.

Mouthparts. Palpus with two immovable hooks, the movable hook with a second small seta at its base. One large and one small seta present on each lateral margin of the mental cleft.

Fourth instar. Antennae five-segmented; pigmentation of segments as in the preceding instar. Tarsi three-segmented in this and in remaining instars, by subdivision of the distal segment. Wingpads appearing externally as minute lateral ridges in meso- and metathoracic regions. Gills with three pigmented cross-bands, the central one darkest, closer to the proximal band than to the distal.

Mouthparts. Unchanged except in absolute size.

Fifth instar. Antennae five-segmented, the greater part of the first, and distal part of second and fourth segments pigmented. A small dorsolateral tubercle is apparent directly behind each eye, and a dark band of pigment about the width of the eye extends back laterad from the proximal segment of each antenna to the level of the mesothoracic coxae. Metathoracic wingpads about 0.23 mm. in length. Dorsal gill slightly curved ventrad.

Mouthparts. The third (median) immovable hook now present on each labial palpus.

Sixth instar. Antennae six- or seven-segmented, distal parts of segments one and three pigmented, terminal segment dark with exception of tip. Posterolateral margins of head angular, post-ocular tubercles well developed. Wingpads as in Plate II (fig. k1). At this stage the female gonapophyses first appear externally as three pairs of ridges, the ventral pair at the hind margin of the 8th sternum, the inner and lateral pairs on the 9th sternum.

Mouthparts. An accessory tooth is now present at the base of the first incisor of the right mandible, and the galeolacinia of the maxilla bears three additional small hooks. The mouthparts hereafter show little change in relative proportions, except for a lengthening of the body of the mentum.

Seventh instar. Antennae seven-segmented. Wingpads as in Plate II, fig. k2. Female gonapophyses as in Plate II, fig. m2.

Eighth instar. Antennae seven-segmented. Wingpads as in Plate II, fig. k3. Gonapophyses of female as in Plate II, fig. m3. The male gonapophyses are now evident as minute ridges on the posterior part of the ninth sternum (Plate II, fig. p1). The cercoids are first apparent in this instar, one on each side of the dorsal gill.

Ninth instar. Antennae seven-segmented. Wingpads as in Plate II, fig. k4. Male and female gonapophyses as in Plate II, figs. p2 and m4, respectively. Of the three femoral crossbands, the two distal ones are most pronounced, the space between conspicuously light in color. Three less conspicuous crossbands also appear on each tibia. Cercoids about 0.14 mm. in length.

Tenth instar. Antennae seven-segmented, the basal segment as long as the rest together. Wingpads as in Plate II, fig. k5. Two double rows of blackish pigment spots appear dorsolaterally along the abdomen as far as segment eight, the hind margin of each tergum bearing four

spots. Gonapophyses as in Plate II, figs. m5 and p3. Cercoids about 0.23 mm. in length.

Eleventh instar. Antennae seven-segmented, the proximal one slightly longer than the remaining segments together. Postocular tubercles now exceeding the eyes in height. Wingpads as in Plate II, fig. k6. Gonapophyses as in Plate II, figs. m6 and p4, the ventral valves of the ovipositor longer than laterals or inners. Dorsal gill considerably shorter than laterals, the tip pointed, not rounded as in *aequabile.* Cercoids about 0.28 mm. in length.

Twelfth instar. Antennae seven-segmented, the proximal segment thickest at the base, longer than the remaining segments together. The wingpads double their length and almost triple their width at this stage. Gonapophyses of female as in Plate II, fig. m7, heavily sclerotized, the lateral processes rounded distally and very setose, the ventral processes pointed and longer than laterals or inners. Gonapophyses of male (Plate II, fig. p5 smaller and less pointed than those of the mature male nymph of *aequabile.* Cercoids about 0.49 mm. in length. The mature nymph of *maculatum* is shown in Plate IV (2).

Agrion aequabile Say

DESCRIPTION OF INSTARS

(See Table III)

Mouthparts are not described for this species, since, apart from their slightly larger size, they appear to be identical with those of *A. maculatum* described above.

First instar. Nymph almost identical in general appearance with the first instar nymph of *A. maculatum,* except that the antennae and gills are slightly longer and more slender than in the latter. Tarsi one-segmented. Tenth abdominal segment dark.

Second instar. Antennae four-segmented. Femora and gills each with a single distal band of pigment. Tarsi one-segmented. Tenth abdominal segment dark as before.

Third instar. Antennae five-segmented, the second segment darkly pigmented distally, distal parts of segments 3 and 4 and the whole of 5, greyish in color. A dark strip now extends dorsolaterally from the basal segment of each antenna, to the mesothoracic coxae. These stripes persist through remaining instars and later extend along the outside of the proximal antennal segment. Femora with three dark crossbands, the distal one broadest; tibia with two lesser proximal bands. Gills with three dark areas, the two distal ones most pronounced. Tarsi three-segmented in this and in remaining instars. Wingpads apparent as two pairs of minute dorsolateral ridges on meso- and metathorax.

Fifth instar. Antennae six-segmented, segments 2–6 inclusive pigmented distally. Lateral gills becoming triquetral, dorsal gill shorter, lamellate, curved ventrad and rounded off at the tip.

Sixth instar. Antennae seven-segmented. Dark spots of pigment are now evident on the dorsolateral parts of abdominal segments 1–8 inclusive, one pair per segment. Wingpads as in Plate III, fig. j1.

TABLE III

Agrion aequabile Say

EXTERNAL MEASUREMENTS OF NYMPHAL INSTARS, AVERAGES AND RANGES, mm.

Figures in brackets represent number of individuals upon which each measurement is based.

(Av.—average; R.—range.)

CHARACTER		INSTAR											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Head width	Av.	(7) .36	(15) .44	(20) .50	(20) .58	(18) .67	(16) .76	(17) .86	(18) 1.03	(36) 1.32	(46) 1.76	(67) 2.49	(27) 3.18
	R.	.32–.41	.41–.46	.46–.52	.55–.64	.64–.75	.70–.87	.78–.96	.91–1.14	1.08–1.48	1.48–2.06	1.94–2.85	2.85–3.48
Length prox. seg. antenna	Av.	(7) .18	(15) .27	(20) .37	(20) .48	(18) .65	(17) .80	(17) 1.01	(17) 1.39	(36) 1.86	(46) 2.56	(68) 3.48	(27) 3.82
	R.	.14–.23	.23–.29	.32–.43	.41–.58	.55–.81	.61–.90	.90–1.16	1.31–1.54	1.60–2.05	2.28–3.13	2.85–3.93	3.42–4.22
Length antenna	Av.	(7) .51	(15) .68	(20) .89	(20) 1.10	(18) 1.42	(17) 1.72	(16) 1.97	(18) 2.64	(35) 3.39	(44) 4.46	(66) 5.92	(20) 6.50
	R.	.46–.58	.61–.72	.78–1.01	.99–1.28	1.28–1.68	1.42–2.00	1.88–2.38	2.51–2.85	3.02–3.70	3.99–5.47	5.02–6.67	5.81–7.30
Length lateral gill	Av.	(7) .70	(15) .99	(18) 1.48	(18) 2.20	(17) 3.02	(16) 3.86	(17) 4.75	.....	.....	.....	.....	.....
	R.	.67–.75	.84–1.13	1.25–1.71	1.68–2.58	2.44–3.65	3.36–4.49	4.26–5.45	.....	.....	.....	.....	.....
Length dorsal gill	Av.	(5) .63	(10) .94	(10) 1.37	(10) 2.00	(12) 2.62	(11) 3.25	(11) 4.02	.....	.....	.....	.....	.....
	R.	.41–.72	.72–1.04	1.19–1.65	1.62–2.32	1.88–3.16	2.55–3.91	3.51–4.75	.....	.....	.....	.....	.....
Length hind femur	Av.	(7) .60	(15) .87	(20) 1.21	(20) 1.62	(18) 2.19	(17) 2.72	(17) 3.37	(18) 4.05	(35) 5.03	(44) 6.50	(66) 8.26	(25) 8.73
	R.	.55–.64	.75–.96	1.01–1.39	1.28–1.91	1.83–2.64	2.41–3.13	3.07–3.80	3.70–4.50	4.16–5.64	5.70–7.81	6.44–9.06	7.98–9.35
Length front tarsal claw	Av.	(5) .09	(15) .11	(20) .14	(20) .16	(17) .21	(16) .23	(16) .27	(18) .27	(35) .30	(43) .37	(66) .46	(25) .52
	R.	.09–.12	.10–.14	.07–.17	.12–.20	.14–.26	.20–.29	.26–.32	.23–.34	.23–.40	.34–.40	.40–.57	.40–.63
Length labial cleft	Av.	(7) .03	(15) .08	(20) .14	(20) .21	(18) .31	(16) .43	(17) .57	(18) .72	(35) .99	(47) 1.42	(68) 2.01	(27) 2.35
	R.	.....	.07–.09	.12–.20	.19–.26	.23–.41	.32–.52	.49–.67	.63–.85	.85–1.20	1.25–1.77	1.60–2.28	2.05–2.56
Length metathoracic wing pad	Av.	.....	.....	.....	.....	.....	.....	.....	(12) .56	(22) .95	(30) 1.74	(43) 3.47	(9) 6.84
	R.	.....	.....	.....	.....	.....	.....	.....	.46–.63	.57–1.20	1.14–2.22	3.08–3.82	6.33–7.30

Seventh instar. Antennae seven-segmented. Wingpads as in Plate III, fig. j2. At this stage the female gonapophyses may sometimes be discerned with difficulty, the ventral valves showing as two minute central ridges at the posterior border of the eighth abdominal sternum.

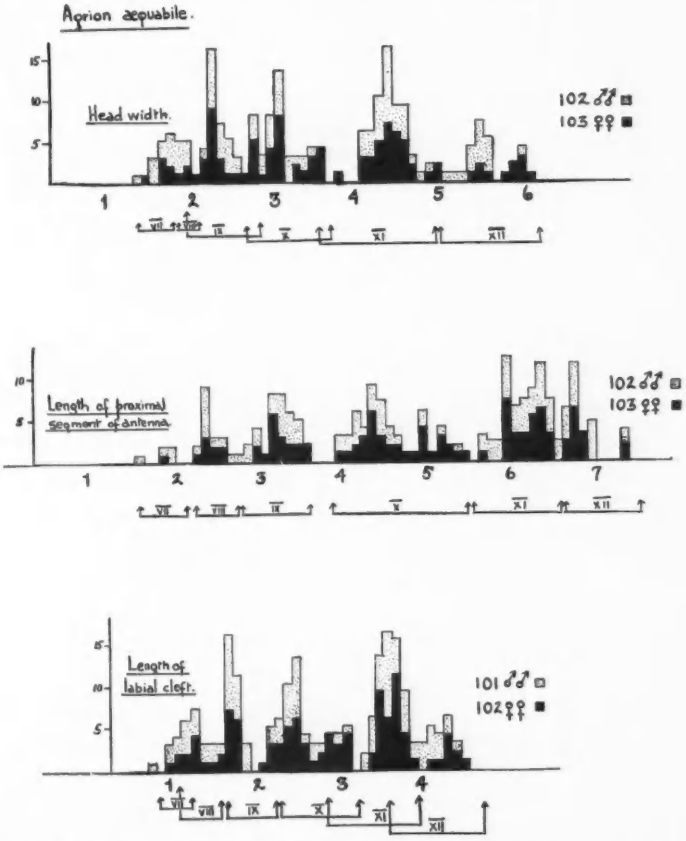

Fig. 5. Frequency histograms for three nymphal characters of *A. aequabile*, instars VI–XII. Ordinates represent frequency of occurrence, abscissae, observed magnitudes in squares in Whipple disc (1 square—0.57 mm.).

In most cases, however, all three pairs of female structures make their first appearance together in the eighth instar. It is to be noted that the length of the proximal antennal segment exceeds the head-width for the first time in the seventh instar.

Eighth instar. In this and in succeeding instars, the general body coloration is variable, ranging from greenish or grayish brown to very

dark brown. The dark spots on the dorsum of the abdomen become larger and are often supplemented by other irregular markings. Two low tubercles, one behind each eye, are slightly evident on the dorsolateral parts of the head. Wingpads as in Plate III, fig. j3. Gonapophyses of the female as in the seventh instar of *maculatum*, gonapophyses of male appearing for the first time (Plate III, fig. n1). Cercoids just visible under high magnification.

Ninth instar. Antennae seven-segmented. Wingpads as in Plate III, fig. j4. Male and female gonapophyses as in Plate III, figs. n2 and l2. Distinction on sight can now be made between nymphs of this species and those of *maculatum* at the same stage. The abdomen, legs, and proximal segment of antenna are longer and more slender than those of the latter species, and the head is narrower. Cercoids about 0.14 mm. in length.

Tenth instar. Antennae seven-segmented. Wingpads as in Plate III, fig. j5. Male and female gonapophyses as in Plate III, figs. n3 and l3. Those of the female are growing much more rapidly than is the case in *maculatum*, where the valves grow through seven instars before maturing. Cercoids about 0.25 mm. in length.

Eleventh instar. Antennae seven-segmented. Wingpads as in Plate III, fig. j5, more than doubling their size of the preceding instar. Gonapophyses as in Plate III, figs. n4 and l4 the distal portions of the processes dark and heavily chitinized. Cercoids about 0.41 mm. long.

Twelfth instar. Antennae seven-segmented, segments two and three becoming further elongated. The wingpads again more than double their length and breadth (Plate III, fig. j6). Gonapophyses as in Plate III, figs. n5 and l5, the lateral processes of both sexes longer and more pointed than in *maculatum*. Cercoids reaching a maximum length of about 0.87 mm. The fully developed head-tubercles do not exceed the eyes in height as do those of *maculatum*. The nature nymph of *aequabile* is shown in Plate IV, fig. (1).

SUMMARY

1. An account is given of methods used in an attempt to rear *Agrion aequabile* and *Argion maculatum* from the egg to maturity.

2. The life histories of both species are briefly described.

3. The nymph of *A. maculatum* passes through eleven to twelve instars, reaching maturity in a year or less. The nymph of *A. aequabile* passes through twelve to thirteen instars, and by reason of its slower rate of growth, is estimated to require two or more years to mature.

4. The nymphal instars of each species are statistically treated and described, with an account of methods used in determining species and instar of collected material.

The above investigation was carried out under the direction of Dr. E. M. Walker, to whom the author is grateful for advice and criticism in the preparation of this paper.

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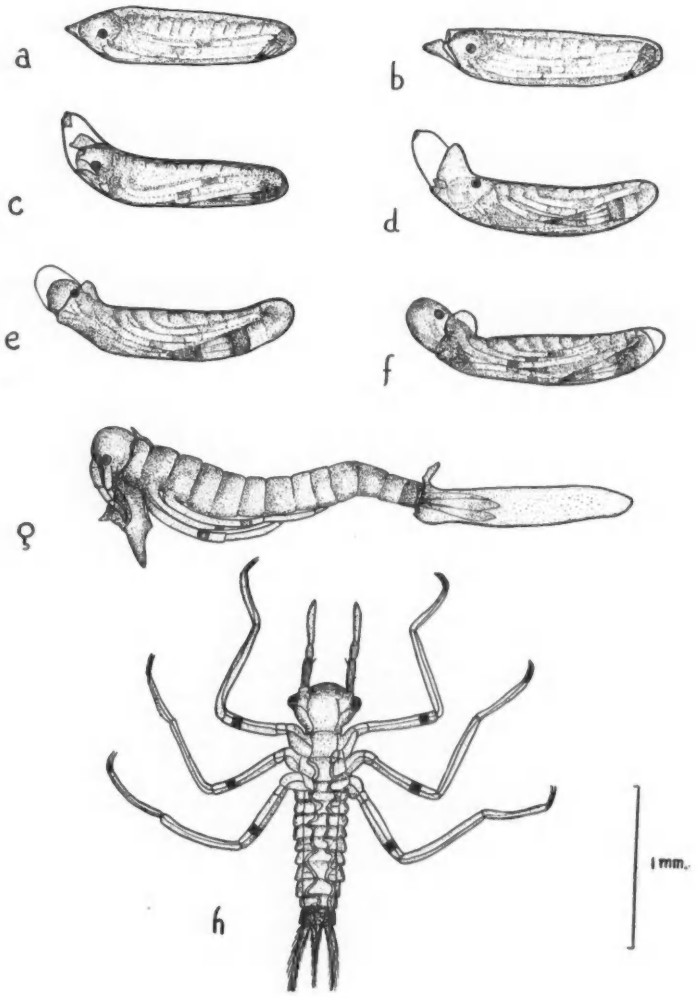
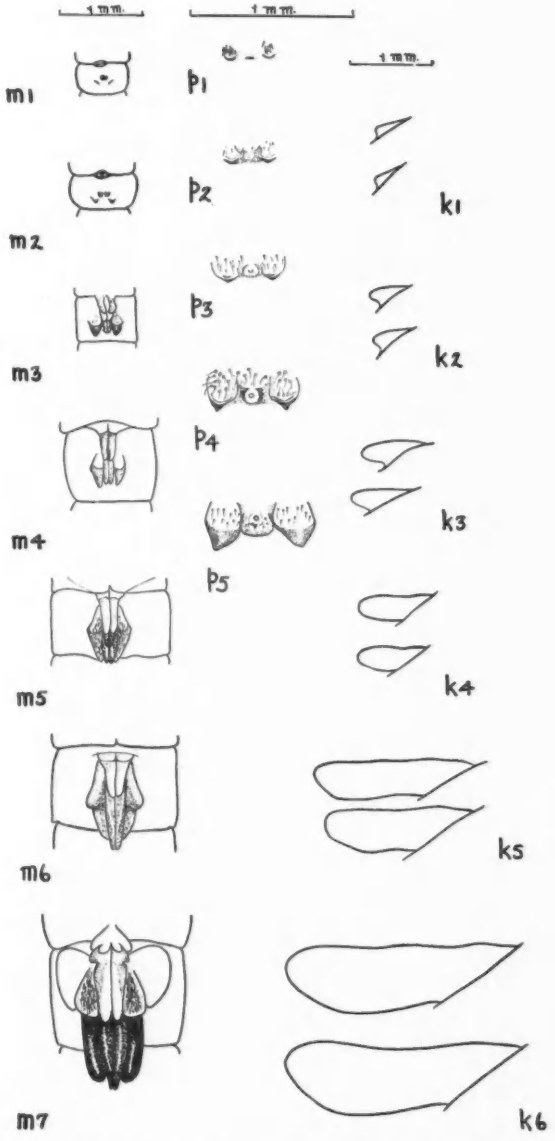
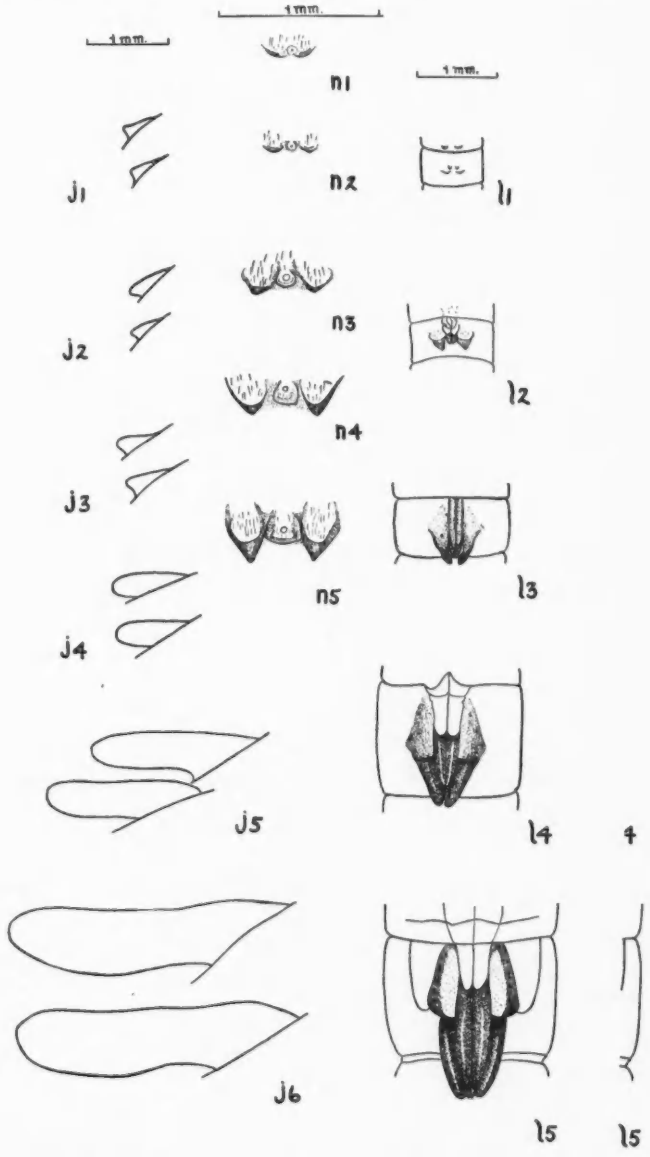


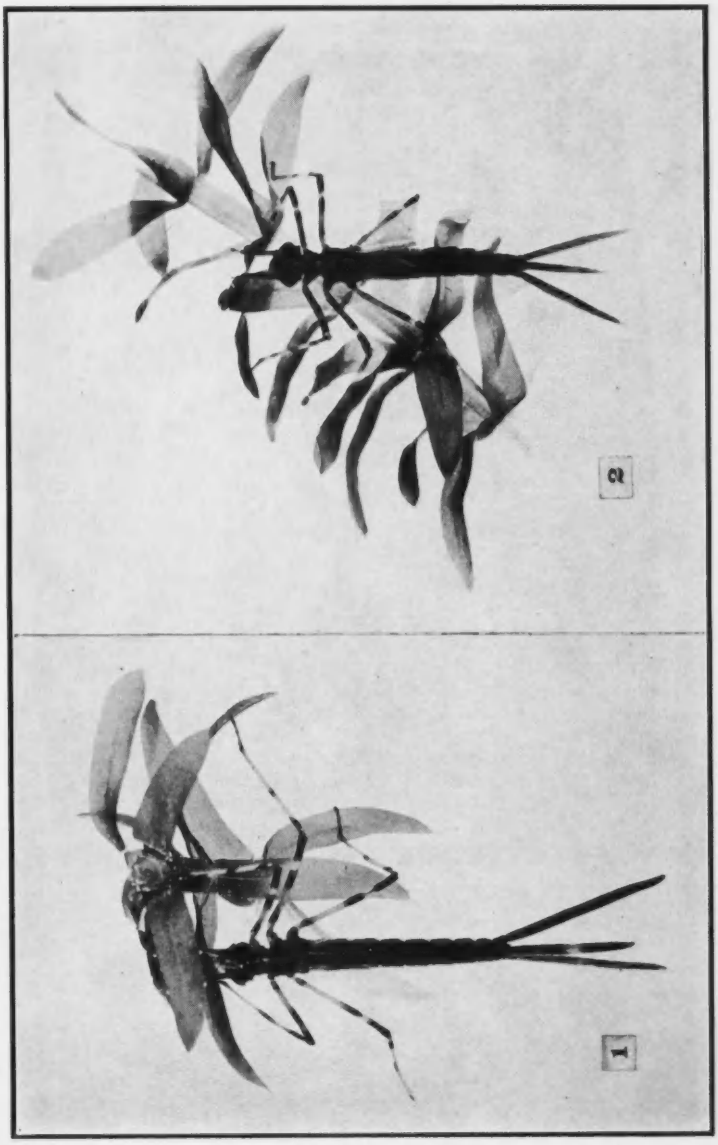
Successive stages in hatching of the egg of *A. maculatum*.



A. maculatum: Development of valves of the ovipositor, structures of 9th abdominal segment of ♂ and wingpads.



A. aequabile. Development of valves of the ovipositor, structures of 9th abdominal segment of ♂ and wingpads.



Mature nymphs of *A. maculatum* (fig. 2), and *A. aequabile* (fig. 1), natural size.

DIGESTIVE ENZYMES OF THE LARVA OF THE CATTLE GRUB HYPODERMA LINEATUM (DE VILLIERS)

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The present paper describes a search for digestive enzymes of the alimentary canal of the third-instar larva of *Hypoderma lineatum* (De Villiers).

Studies on this parasite have involved principally its biology and control. Little has been done on its physiology, and this study is presented as a step in that direction. The results also indicate the general types of food which may be assimilated by the parasite.

SOURCE AND PREPARATION OF MATERIAL

Specimens used were third-instar larvae collected from slaughtered cattle at abattoirs in Des Moines, Iowa, and St. Paul, Minn., during the winter of 1938.

The technic employed for extraction of the larvae from freshly removed hides was to place the thumb and forefinger laterad of the cyst on the subcutis side, insert the point of a sharp tenaculum beneath the cyst wall, and open it by a straight pull. Pressure with the fingers then forced the specimen from the open cyst. Care was taken when inserting the tenaculum not to puncture the larva. This was much faster than extraction through the natural opening of the cyst, and enabled easy removal of those specimens in cysts with small or partly plugged openings.

Dissections of larvae were sometimes made the same day, but usually after being stored at 2° C. for 18 to 48 hours, rarely longer. At such a temperature apparent activity ceased, but viability was maintained. Specimens were washed free of cystic exudate before being stored, as this material has an adverse effect on viability. There appeared to be no appreciable difference between the amount of the intestinal contents of the stored larvae and that of the freshly collected specimens.

Specimens were pinned in dissecting dishes, ventral side down, covered with distilled water, and slit along the mid-dorsal line. The salivary glands were then removed, slit, washed twice in distilled water, and placed in the extraction medium. No attempt was made to test the contents of the salivary glands for enzymes. The intestine was likewise removed and washed. It was then divided into fore intestine, mid

[1]The writer is indebted to H. O. Schroeder of this Bureau for collection of the specimens at St. Paul, Minn. He wishes also to thank R. W. Wells for constructive criticism of the manuscript.

intestine, and hind intestine and malpighian tubes. The mid and hind portions were opened and the contents removed for tests. The tissue after being washed was placed in extraction medium. Toluene was used throughout as a preservative. Because the fore intestine is exceedingly small and practically devoid of contents, no attempt was made to extract anything other than the washed tissue.

GROSS ANATOMY OF THE DIGESTIVE TRACT

Salivary glands. These are a pair of transparent elliptical bodies containing clear fluid and lying in a bilateral position to the posterior half of the esophagus. Each gland opens into a duct 2.3 mm. in length. The two ducts unite to form a single duct of about the same length as one branch, which opens into the anterior pharyngeal region.

The fore intestine. Posterior to the pharynx the fore intestine continues as a simple, nondilated, straight tube, the esophagus, with a mean length of 6.166 mm. and a mean diameter of 0.2 mm. It is usually transparent or translucent with reflected light, and opens posteriorly into the mid intestine via an enlarged region, until recently designated as the proventriculus. This region has been, and is, considered by many to be the posterior termination, and an integral part, of the fore intestine. Snodgrass (1935), however, designates the structure, in adult Diptera, as the cardia, and says it is the anterior part of the ventriculus, and the origin of the peritrophic membrane. It is not known whether this region in *Hypoderma* larvae is analogous with the cardia of adult Diptera. In making divisions of the alimentary canal for enzyme determination it was considered as a part of the fore intestine. Since the structure apparently does not secrete enzymes, its anatomical relationship in this instance appears to be immaterial. It is white and opaque and measures 1.5 mm. in diameter and about the same in width.

The mid intestine. From the anterior end of the ventriculus to the malpighian tubes the mid intestine has a mean length of 90.5 mm. and a mean diameter of 2.0 mm. No gastric ceca could be found. It is the longest portion of the digestive tract and is considerably convoluted within the body. The greatest diameter is anterior, with a gradual decrease posteriorly. The color is usually a cream or buff, resembling pus. Ono (1932) states that the ingesta is pus upon which the larvae have fed. In an occasional specimen the ingestum is reddish or brown. This is probably extracellular hemoglobin, as erythrocytes were not noted in several specimens examined. It has been shown, Simmons (1939), that hemorrhage is rare, and this accounts for the infrequency of ingested blood. In older specimens that have turned to ultimate brown or black the intestinal contents are reduced in quantity and have a thicker consistency and a deeper yellow color.

The hind intestine. The mean total length, including the rectum, is 43.0 mm. The diameter varies considerably but averages about 1.1 mm. The hind intestine may be opaque, with transparent to semi-transparent dilatations containing clear fluid. Cream-colored ingesta resembling that usually found in the mid intestine may be present, while in some specimens contents are almost entirely lacking.

The rectum averages 3.05 mm. in length. It usually contains a clear or slightly cloudy fluid rendering it transparent or semi-transparent.

The malpighian tubes. These are four in number. A single duct approximately 0.5 mm. in length arises on each side of the anterior end of the hind intestine. Each duct divides, forming two tubes with an average length of 21.0 mm. and a dimaeter ranging from 2.0–4.0 mm. The color is normally a deep bright yellow. Enzymes present in the contents or tissues of the malpighian tubes were not determined.

HYDROGEN-ION CONCENTRATIONS OF THE CONTENTS OF THE DIGESTIVE TRACT AND THE HEMOLYMPH

The hydrogen-ion concentration in various regions of the digestive tract was ascertained prior to tests for enzymes. The mid and hind intestines were each divided into fore, mid, and hind portions, and the contents of each of these tested. These tests served as a guide for pH adjustments of the extract and substrate, and gave a clue to the enzymes that might be active in such pH ranges. Tests were conducted by the Brown Colorimetric Method without correcting for the protein error (Brown, 1924).

Table I gives the results obtained.

TABLE I

pH OF CONTENTS OF DIGESTIVE TRACT OF *Hypoderma lineatum* LARVAE

Test Number	Postcollection Age of Specimens		pH of Contents of						
	Tested Day Collected	Stored at 2° C. Hours	Salivary Glands	Mid Intestine			Hind Intestine		
				Fore	Mid	Hind	Fore	Mid	Hind
1	x			6.4		7.3		7.6	
2	x			7.0	6.2	6.4			
3		240		6.4	6.2	6.4			6.4
4		18	6.8				7.0	7.8	7.2
5		do			6.3				6.2
6		do	7.0				8.0	8.0	7.2
7		do	7.0						
8		do	6.9				7.7	8.0	7.9
9		do	7.0						

Contents of all portions of the digestive tract tested, except the regions of the hind intestine, were indicated in most instances to have a slightly acid pH. The mid section of the hind intestine appeared to have the least concentration of H ions, while the mid section of the mid intestine showed the greatest concentraiton.

Results of colorimetric determinations of the pH of the hemolymph are shown in Table II.

TABLE II

pH OF BODY FLUID (HEMOLYMPH) OF LARVAE OF *Hypoderma lineatum*

Test Number	Post Collection Age of Specimens		pH
	Tested Day Collected	Stored at 2° C. Hrs.	
1		48	6.9
2		do	6.9
3		do	6.6
4		do	6.6
5	x		6.8
6	x		7.0
7		240	6.6
8		24	6.8

DIGESTIVE ENZYMES

Technic. In most instances 50 per cent glycerol extracts of the various tissues, or contents, being tested were used. The concentration varied somewhat with the material available. Typically it consisted of material from about 12 larvae in one and one-half cubic centimeters of extractive. The washed tissue was triturated in the glycerol with sand and extracted, with occasional shaking, for 24 to 48 hours. The supernatant fluid was then used for tests. These were conducted in micro tubes 4 by ½ inches or 4 by ¼ inches depending upon the quantity of material used. All tubes were incubated at 37.5° C. from 1 to 96 hours. In the case of liquid substrates usually one-fourth or one-half cubic centimeter was used to about half or less of that amount of extract. Controls conducted with heated extract were all negative and will not be referred to again.

Methods for detecting enzymatic digestion of substrates are readily available in various books and articles (Babers and Woke, 1937; Fletcher and Haub, 1933; Hawk and Bergeim, 1937; Hobson, 1931; Roy, 1937; Swingle, 1925, 1928; and Waksman and Davison, 1926) and will be referred to here only briefly.

The pH of the extracts was adjusted as follows: For anylase, lactase, maltase, lipase, trypsin, and rennin, to pH 7.2–7.6; for pepsin, to pH 2.2; for erepsin, to pH 8.0; and for glycogenase, to pH 7.0. Sodium carbonate or hydrochloric acid was used in making the adjustments.

The hydrolysis of nonreducing to reducing sugars by amylase, invertase, and glycogenase was tested for by the use of Benedict's reagent, Fluckiger's test for reducing sugars, or the osazone test. The iodine test for detection of nonhydrolyzed starch was also used in determining amylase activity.

Since lactose and maltose reduce Benedict's and Fehling's solutions, these reagents could not be used for detecting enzymatic activity on those substrates. Barfoed's solution is not reduced by either lactose or maltose until after long heating; therefore reduction after three minutes'

heating was used as a criterion of digestion. The osazone test was usually employed as an auxiliary measure.

In the determination of lipase activity the bromo-thymol blue emulsion test was employed, olive oil and acacia being used as a substrate and bromothymol blue as an indicator. Hydrolysis of fat was indicated by a change in the color of the substrate from blue to greenish yellow or yellow, after incubation.

Rennin acts upon the casein of milk, converting it to soluble paracasein, and the latter is precipitated as insoluble calcium paracaseinate by calcium ions (Hawk and Bergeim, 1937). As a substrate, therefore, 1 cubic centimeter of milk with 1 drop of M $CaCl_2$ was used per tube (Yeager, 1935). Coagulation within one hour was taken as a criterion for rennin activity.

Carmine-stained blood fibrin was used as a substrate for pepsin, and Congo-red-stained fibrin as a substrate for trypsin. Digestion was indicated by release of the stain into solution and by diminution in size, or disappearance of the fibrin particle. The term "trypsin" is used to designate the enzyme or enzymes digesting fibrin at the slightly alkaline pH used.

Tests for erepsin were made by the Sorenson method as modified by Swingle (1928), and the biuret test for peptones as given by Hawk and Bergeim (1937).

RESULTS

Ten enzymes were tested for. The results obtained are given in Table III. The relative concentration of enzymes in various regions of the intestine are indicated by the number of plus signs present.

TABLE III

ENZYMES IN THE DIGESTIVE TRACT OF LARVAE OF *Hypoderma lineatum*

Enzyme	Substrate	Contents of		Tissue of			
		Mid Intestine	Hind Intestine	Salivary Glands	Fore Intestine	Mid Intestine	Hind Intestine
Amylase	Soluble starch	—	—	—	—	—	—
Lactase	Lactose	+	—	—	—	—	—
Maltase	Maltose	+	+	—	—	—	—
Invertase	Sucrose	+	—	—	—	—	—
Glycogenase	Glycogen	++	—	—	—	+	—
Lipase	Olive oil	++	+	—	—	+	+
Rennin	Milk	++	—	—	—	—	—
Pepsin	Fibrin	—	—	—	—	—	—
Trypsin	Fibrin	+++	+	—	—	++	—
Erepsin	Peptone	++	+	—	—	++	+

With the exception of amylase and pepsin, all the enzymes tested for were found. No enzymes were found to be secreted by the salivary glands or fore intestine.

The mid intestine contents were rich in enzymes. Lactase, invertase, and rennin were found only in the contents. These enzymes apparently are not a secretory product of the larva itself, but probably originate from bacteria in the digestive tract, or are obtained with ingesta from the cystic exudate.

As indicated by the tests with macerated tissue, the mid intestine secretes more enzymes than any other region of the alimentary canal. The tissue of this region, free from ingesta, was positive for glycogenase, lipase, trypsin, and erepsin. Glycogenase was the only carbohydrase found to be secreted by the larva.

The hind intestine contents contained maltase, lipase, trypsin, and erepsin. It is indicated that lipase and erepsin are synthesized in this region by the larva. Maltase is either passed on with ingesta from the mid intestine or is synthesized in situ by symbiotic micro-organisms, while the trypsin originates in the mid intestine.

DISCUSSION

These studies tend to show that larvae of *Hypoderma lineatum* secrete enzymes which digest proteins, breaking them down via trypsin and erepsin to amino acids. Fats are hydrolyzed, and the glycogen digested is a source of sugar.

It seems likely that most of the digestion occurs in the mid intestine. Proteins escaping complete digestion in this region, if broken down into peptones, may be converted to amino acids by erepsin of the hind intestine. Erepsin activity in this region, however, is much weaker than in the mid intestine. No enzymes that can digest blood fibrin were found to be secreted by the hind intestine.

Fat is digested mainly in the mid intestine, but that escaping may be acted upon by lipase of the hind intestine.

The ingesta of the larvae may contain several carbohydrates not secreted by the larvae themselves, such as lactase, maltase, and invertase. It is not known whether these enzymes are synthesized by bacteria in the intestine, or in the cystic exudate and subsequently ingested by the larva. Some of them may originate from broken down tissue, or even from viable leukocytes of the exudate. Such enzymes, however, are usually predominantly proteases. The probable action of these carbohydrases is in the hydrolysis of their respective sugars in the exudate. These sugars may originate from cytolysis of bacterial and tissue cells, and from infiltration of carbohydrate-bearing body fluids.

As previously surmised by Simmons (1939), skin perforation by the larvae is probably due mainly to cytolysis of the tissue by proteolytic enzymes. The results of these studies indicate that these enzymes are not secreted by the salivary glands or any portion of the fore intestine. The excreta, judging from the enzymes of the hind intestine, are relatively weak in proteases. It appears, therefore, that if enzymatic liquefaction of tissue for the purpose of perforating the skin does occur it is accomplished principally by enzymes regurgitated with ingesta from the mid intestine. Ono (1932), writing of esophageal larvae, says that squeezing the larva causes a free disgorgement from the mouth, but not from the anus.

SUMMARY

A qualitative study of the digestive enzymes of the third-instar larva of *Hypoderma lineatum* showed the following to be present: Lactase, maltase, invertase, glycogenase, lipase, rennin, trypsin, and erepsin. Of these only glycogenase, lipase, trypsin, and erepsin are apparently secreted by the larvae, the others probably being products of bacteria in the intestine, or an ingestation along with the cystic exudate. Digestion occurs mainly in the mid intestine, where proteins may be broken down to amino acids, and fats and glycogen digested. Small quantities of lipase and erepsin were found in extracts of the macerated tissue of the hind intestine, and these may act on fats and peptones escaping from the mid intestine.

The gross anatomy of the digestive tract is briefly described.

Hydrogen-ion determinations of the intestinal contents by uncorrected methods indicated a slightly acid pH for all regions except in the hind intestine, where the reactions were predominantly alkaline.

The hemolymph was indicated to have a slightly acid reaction.

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THREE NEW SPECIES OF NEARCTIC TRICHOPTERA

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The three following species are described primarily so that the names may be used in other papers. Except where noted, types described in this paper are deposited in the collection of the Illinois State Natural History Survey. I am indebted to my co-worker, Dr. C. O. Mohr, for assistance with the drawings.

Cernotina ohio new species

The male genitalia resemble closely those of *spicata* Ross, differing, however, in lacking the ovate ventral lobe at the base of the cerci, and in the different shape of the apex of the claspers.

Male—Length, 5 mm. Color of entire insect straw-colored. General structure, including wing venation, spur count, and conformation of head and body, exactly as for other members of the genus. Genitalia as in fig. 1. Ninth and tenth tergites, fig. 1-A, fused. Apex of tenth tergite produced into a pair of long, thin, triangular lobes clothed with fairly long, slender setae. Cerci with base only moderately robust and tapering rapidly to a long, curved, whip-like apex which is again constricted near the end; only the basal portion bears setae. Beneath the tenth tergite and between the claspers arise a pair of stout, sinuate, spur-like processes which are dark at the tip. Claspers, fig. 1-B, with the dorsal arm shorter than ventral portion, tipped at the apex with a few stout setae; body of the claspers more or less rectangular viewed from the side, clothed with abundant fine setae; the extreme apex is only slightly oblique and forms a short, thin projection, as in fig. 1. Aedeagus semimembranous and tubular, typical for genus.

Holotype, male—Put-in-Bay, Ohio, July 19, 1937, D. M. DeLong. *Paratypes*—Same data as for holotype, but July 8, 1 ♂; July 20, J. N. Miller, 1 ♂; July 29, Miss Anne C. Marshall, 1 ♂; July 30, Miss Anne C. Marshall, 1 ♂. Two paratypes are deposited in the Ohio State University collection.

Rhyacophila teddyi new species

This species differs from *carolina* Banks in the more declivous tenth tergite which bears no sclerotized points but

instead a pair of rounded projections which form a wide, excavated mesal area bearing a median carina, fig. 2-B.

Male—Length, 11 mm. Color of body and appendages dark brown; head, legs, and various sclerites of thorax irregularly shaded with lighter shades of brown or straw color; wings irregularly spotted with lighter areas, these areas and other parts of the body clothed with small patches of light pubescence. General structure typical for genus.

Genitalia as in fig. 2. Ninth tergite, fig. 2-A, cylindrical, narrowed ventrally. Tenth tergite wide and robust, rounded dorsally, with a pair of lateral wing-like extensions forming an excavated mesal portion which has a median carina, fig. 2-B; below this are several small sclerites as illustrated. Claspers with basal segment wide, produced and angulate on the caudo-ventral margin; the apical segment is short and deeply incised on the apical margin to form a heel and toe, the outer surface clothed with fine scattered setae, the inner with two patches of dense, short, dark setae near the upper and lower margins. Aedeagus, figs. 2-C and D, with a basal pair of extensile membranous arms, each containing an apical slender rod clothed at its apex with appressed spicules; the central part of the aedeagus consists of a scoop-like ventral part above the center of which arises a vertical plate bearing at its apex a ventral process with a truncate tip and a slightly stouter dorsal process with an upcurved tip; the dorsal margin of the plate forms a concave area produced laterally into a pair of prominent and somewhat angulate lobes.

Holotype, male—Gatlinburg, Tennessee, LeConte Cr., June 16, 1938, T. H. Frison and T. H. Frison, Junior. *Paratypes*—Tennessee—New Found Gap: June 19, 1938, T. H. Frison and T. H. Frison, Junior. North Carolina—Smokemont: June 14, 1935, H. H. Ross.

Neotrichia okopa new species

This species is most closely related to the Mexican *Exitrichia oxima* Mosely, but differs from it in the triangular claspers and different shape of the lateral lobes of the ninth segment and other characters of the genitalia. A study of the *bursa copulatrix* of this and other related species shows that the genus *Exitrichia* can be included within *Neotrichia*. It seems to me that the subdivision of this latter genus, on the basis of genitalia, can be expressed most conveniently by the use of groups or subgenera.

Male—Length, 1.8 mm. Color of body and appendages a uniform medium shade of brown. General structure, including wing venation, spur count, and other characters of head and thorax, identical with other described members of the genus. Diagnostic characters apparently confined to genitalia, fig. 3.

Genital capsule, fig. 3-E, sharply retracted within eighth sternite, the lateral lobes pointed. Tenth tergite, fig. 3-B, confluent with ninth, produced into a broad apex bearing a long spine at each corner and with the central portion produced into a well-marked lobe. On each side of this is a semimembranous fold which has a distinct appendage from the lateral view. From the lower portion of the ninth segment there arises a spatulate lobe, fig. 3-E, with long, scattered setae clustered chiefly on the caudal and ventral margins. Between these are a pair of short, stout, heavily sclerotized structures which are usually concealed by other parts of the genitalia. Claspers somewhat triangular from both the ventral and lateral aspects, figs. 3-E and F; just beyond their middle there arises a pair of dorsal protuberances which may be seen as short, sharp points in silhouette; the claspers are dark and heavily sclerotized and bear very few setae.

Female—Size and general color similar to male. Seventh sternite slightly angulate on the meson. Eighth sternite, fig. 3-D, tapering very slightly to apex, the lateral and ventral portions weakly sclerotized to form a "V" which reaches half way to the base; the membranous apex bears a ring of about a dozen setae; between this ring and the "V" is a sclerotized duct opening which is somewhat pointed at the apex and emarginate at its base. *Bursa copulatrix* as in fig. 3-C; the base has a pair of short "legs" below the basal band, and the apical portion is a semimembranous process rounded at the apex and divided up the meson for almost its entire length.

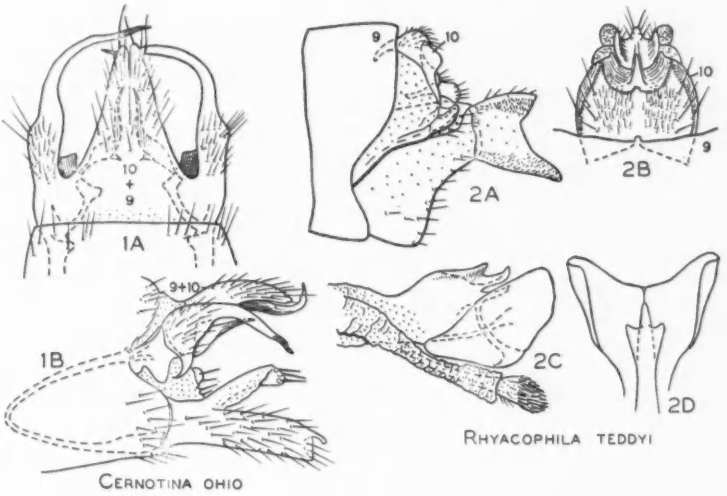
Holotype, male—Athens, Pennsylvania, August 5, 1937, along Susquehanna R., J. H. Eddleston. *Allotype, female*—Same data as for holotype. *Paratypes*—Same data as for holotype, 7 ♂, 21 ♀. Ohio—Put-in-Bay: August 13, 1937, Miss Anne C. Marshall, 2 ♂; August, 1937, C. O. Mohr, 1 ♂. Oklahoma—Reagan: June 1, 1937, along Pennington Cr., H. H. Ross, 1 ♂; June 4, 1938, along Pennington Cr., Mrs. Roy Weddle, 3 ♂. Turner Falls State Park: June 2, 1937, along Honey Cr., H. H. Ross, 2 ♂. A series of paratypes are deposited in the Ohio State University collection.

EXPLANATION OF PLATE

Fig. 1. *Cernotina ohio*—A, dorsal view of male genitalia; B, lateral view of male genitalia.

Fig. 2. *Rhyacophila teddyi*—A, lateral view of male genitalia; B, dorsal view of male tenth tergite; C, lateral view of aedeagus; D, dorsal view of apex of aedeagus.

Fig. 3. *Neotrichia okopa*—A, aedeagus; B, dorsal view of male genitalia; C, ventral view of *bursa copulatrix;* D, ventral view of eighth sternite of female; E, lateral view of male genitalia; F, ventral view of male genitalia.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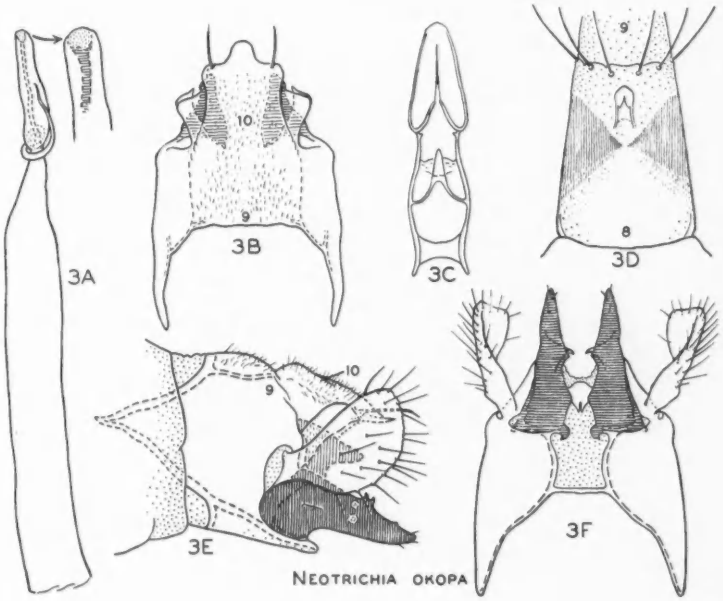
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NEOTRICHIA OKOPA

THE BIOLOGY OF PACHYCREPOIDEUS DUBIUS ASHMEAD (HYMENOPTERA), A PTEROMALID PARASITE OF PIOPHILA CASEI LINNE (Diptera)

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Columbus, Ohio

The small pteromalid wasp, *Pachycrepoideus dubius* Ashmead, is a primary parasite of the common cheese skipper, *Piophila casei* Linne. It attacks the host in the pupal stage and is the only parasite of *Piophila casei* so far as known. This leads to the belief that the earliest record of *P. dubius* dates back to Swammerdam (1758) who observed a small white grub attacking the cheese skipper. Somewhat later Taylor (1861) in his writings on the cheese skipper comments on the effectiveness of a minute Ichneumon in keeping the skipper very much in check during the summer.

More recently *P. dubius* has commanded attention because of its parasitic activities on dipterous pupae, other than *Piophila casei*, and on other hymenopterous parasites. Fullway in 1914 introduced *P. dubius* into the Hawaiian Islands from the Philippine Islands as a dung-fly parasite, and in 1917 reported the propagation and liberation of the same parasite (in Hawaii) against the horn-fly *Lyperosia exiqua* de Meij. A year later Pemberton and Willard (1918) discovered *P. dubius* acting both as a primary and a hyperparasite on *Ceratitis capitata* Wied. and observed the more general phases of its biology. Since 1918 it has been recorded by a number of investigators from a variety of hosts, usually as a primary and occasionally as a secondary parasite.

The biological investigations presented in this paper were conducted by the writer during 1935–37 in the laboratory of biological control, Department of Zoology and Entomology at The Ohio State University. These studies were instigated by Dr. Alvah Peterson, Professor of Entomology, to whom the writer is greatly indebted, not only for materials and the original cultures, but also for much helpful advice and constructive criticism throughout the course of the research.

SYSTEMATIC POSITION AND SYNONOMY

Pachycrepoideus dubius belongs to the family *Pteromalidae*, subfamily *Sphegigasterinae*, and the tribe *Pachyneurini*. The genus was originally described in 1904 by Ashmead who named *P. dubius* as type, but failed to describe the species or even indicate that it was new to science. In 1910 Girault and Sanders redescribed the genus *Pachycrepoideus* Ashmead, describing *Pachycrepoideus dubius* Ashmead, sp. Nov. and designating it as the type species of the genus. To avoid confusion Girault and Sanders retained both the generic and specific names and cited the original authors of these names. Due to this situation *P. dubius* Ashmead has been referred to as *P. dubius* Girault and Sanders.

GEOGRAPHICAL DISTRIBUTION

Coincident with the range of its hosts, the parasite is rather widely distributed. There are records of its occurrence in Argentina, Australia, the Philippine Islands, the Hawaiian Islands (introduced), India, Canada, and the United States (Michigan, Illinois, and Ohio). Its probable presence in Europe is suggested in the writings of Swammerdam to which reference has already been made. The widely scattered records of its occurrence and the parasitization of such hosts as *Piophila casei* and *Musca domestica* Linn. are excellent reasons for believing the parasite to be cosmopolitan in its range.

HOST RELATIONSHIPS

The evidence available indicates that *Pachycrepoideus dubius* is facultative in its host relationships. It is the writer's opinion that *P. dubius* is capable of parasitizing successfully, providing they are accessible to the parasite, any members of the *Cyclorrhapha* in which the pupal stage is spent within the hardened exuvium of the last larval instar, the puparium.

ECONOMIC IMPORTANCE

It is not probable that *Pachycrepoideus dubius* will ever attain economic importance in the control of its hosts in the field.

METHODS

The studies were conducted in the laboratory which was heated throughout the winter. The temperatures ranged from approximately 70° F. to 90° F., but tended to be more constant during the winter months at which time most of the biological investigations were carried out.

The host, *Piophila casei* Linn., was cultured on smoked ham, the used ham being replaced every seven to eight weeks with approximately two pounds of fresh smoked ham. Since mature skipper maggots commonly leave the substrate to pupate elsewhere, a cage was built designed to take advantage of this habit and automatically collect the maggots after leaving the ham. For a complete description and illustration of

this cage, the reader is referred to the Journal of Economic Entomology, Volume 31, page 544 (1938).

Host puparia, not immediately needed, were placed in cloth-stoppered vials or in petri dishes and refrigerated at 34° F. Pupae of *Piophila casei* withstand refrigeration quite well, mortality being less than fifty per cent in material which has been in storage for as long as seven months. For longer periods the mortality among the refrigerated host pupae increased rapidly and after ten months the mortality was usually one hundred per cent. Refrigerated host material, however, proved as suitable as fresh material for rearing *P. dubius*, the parasites ovipositing and developing readily on host pupae which had been under refrigeration for more than a year.

Stock cultures of the parasite were maintained in glass vials (¾x2¾ inches) stoppered with corks. A moistened seedless raisin mounted on a pin inserted in the small end of the cork projects into the vial and provides both food and moisture for the parasites. The parasites are positively phototropic and thus are easily transferred from one vial to another, depending on which is directed toward the source of light. Lots of eighty to one hundred unparasitized host puparia were submitted every other day to recently emerged parasites.

It was found that the parasite would pass through its entire life cycle on host pupae dissected out of the puparium and in this way it was possible to make detailed observations on all phases of its development.

To obtain data, then, on the life cycle and make observations on the immature stages of the parasite, parasitized host pupae were dissected out of the puparium and each placed on a microscope slide in a petri dish (3½ inches in diameter). Covering the bottom of the petri dish were two layers of filter paper which were moistened daily with several drops of water. Too high a humidity is unfavorable to larval development and also encourages the formation on the host substrate of fungous growths by which the parasite larva is rather easily overwhelmed. The petri dishes were kept in a dark cabinet except for brief periods in the morning and evening when observations were made, but otherwise were subject to the same temperatures as existed in the laboratory. The developing parasite larva is mildly negatively phototropic and exposure to long periods of strong daylight apparently has an adverse effect on its development. This was most apparent in the early stages of larval development. The length of the life cycle of parasites which passed through their entire life cycle on host pupae dissected out of the puparium was comparable to that of parasites which completed their development in the normal manner within the host puparium, there being no appreciable difference. The exposed parasite larvae, with careful handling, could be transferred from place to place without showing any ill effects.

In the morphological studies of the larval instars several methods of observation were necessary, none of which in itself was entirely satisfactory. Generally speaking the best results were obtained by first killing and clearing the larval specimens (all instars) in Sinton's fluid (chloral hydrate, 2 parts; phenol, 1 part; pure lactic acid, 1 part); and then

mounting in Berlese's fluid (Peterson 1937). Slide mounts so prepared afford an excellent view of the mouth-parts, its associated structures and the tentorium. Briefly the procedure was as follows:

> The living specimen after being dissected out of the host puparium was placed in a small pH cup (1 by 5 mm. in diameter) half filled with Sinton's fluid. The pH cup was covered with a glass slip, and placed in a petri dish on the cover of which is recorded the necessary data. After the specimen had cleared it was transferred to a microscope slide and the excess Sinton's fluid carefully removed. Several drops of Berlese's fluid were then permitted to fall directly on the specimen and, after preliminary orientation of the larva, the cover slip was applied. Final orientation of the specimen was effected by pressing lightly on the cover slip and moving it around, causing the specimen to roll, until the desired position was attained. For the larger specimens a small cell was constructed of broken cover slips. Berlese's fluid had a tendency to crystalize in many of the slides within a week. It was discovered, however, that ringing such slide mounts with white shellac the second or third day after mounting tended to delay and in many cases prevented crystallization. Most of the slide mounts thusly prepared were still in perfect condition after a year and a half.

The clearing action of Sinton's fluid is complete and rapid, requiring from two to forty-eight hours depending on the size of the specimen which, if desired, may be left indefinitely in the fluid without apparent injury. A larva, when placed in this fluid, tends to remain only partially submerged. After it has cleared, the setae and spines on the portion of the larva projecting above the surface show up to advantage and afford an excellent opportunity for a detailed study of their arrangement. Spines and setae are not visible on submerged specimens.

No distortion of specimens occurred in transfers from Sinton's fluid to Berlese's fluid. Transfers from Sinton's to De Faure's fluid, however, invariably resulted in the collapse of the specimen.

The use of either De Faure's fluid or Berlese's fluid alone into which living specimens were dropped proved satisfactory for first-instar larvae, some excellent mounts showing the mouthparts and tentorium being thus obtained. The clearing action of both fluids is relatively slow and is never complete, even with first-instar larvae. For mounting later instars they were of little value.

The dropping of living larvae in lacto-phenol temporarily showed to advantage the tracheal system, but proved unsatisfactory as a clearing medium.

Dissections of living larvae were made in Ringer's solution. Some larvae were fixed in Kahle's fixative and dissected in seventy per cent alcohol.

Drawings were made with the aid of a camera lucida and a cross-hatch ocular.

DESCRIPTION OF STAGES

Adult. Complete detailed descriptions of both the genus and species are presented by Girault and Sanders' (1910) in the 17th volume of

Psyche, pages 108–117. The writer's taxonomic observations substantiate Girault and Sanders' description of the species with but one exception. Certain discrepancies exist in their descriptions of the adult abdomen of both sexes. Briefly the situation is as follows: Ashmead (1904) in his original description of the genus has characterized quite closely the abdomen of the dried female (fig. 2). Girault and Sanders in their description of the adult female have failed in the writer's opinion to characterize the abdomen of either the living individual or the dried specimen. Their description of the male abdomen is characteristic only for the dried specimen (fig. 4).

Girault and Sanders' description of the female abdomen is presented here verbatim in order to point out the aforementioned discrepancies. "Abdomen distinctly petiolate, moderate in length; the tip of the ovipositor slightly exserted; ventral valves inconspicuous; segments two and three subequal, long, the second longer, both taken together occupying half the surface, the fourth and fifth segments subequal, short, each about half the length of either the second or third segments; caudal margins of the second and third segments in the dorsal aspect straight, in the lateral aspect curved convexly, and in the ventral aspect bilobed, incised at the meson; remaining abdominal segments inconspicuous, the apical segment acute." A comparison of this description with the female abdomen as illustrated in fig. 1 and 2 show the existence of the following obvious disparities:

a. Segment four of abdomen of living female (fig. 1) is definitely longer than segment five; they are not subequal.
   Segments four and five of abdomen of dried female (fig. 2) very short, sixth and seventh segments longer.
b. There is definite visible segmentation after the fifth abdominal segment in both cases.
c. The caudal margins of the second and third segments are definitely concavely curved in the dorsal aspect.

The following is presented as a redescription of the abdomen of a typical, normal, living *P. dubius* female (fig. 1).

> The abdomen smooth and shining, polished black, distinctly petiolate; segments two and three subequal, long, the second longer, together occupying about half the surface, caudal margins of the second and third segments concavely curved in the dorsal aspect, convexly curved in the lateral aspect, bilobed and incised at the meson in the ventral aspect; segment four variably shorter than segment three but longer than segment five; remaining segments subequal, segment five about half the length of segment three, segment seven acute and apparently apical.

Since Girault and Sanders' description of the male abdomen is characteristic only for that of the dried specimen (fig. 4), the following is presented by the writer as a description of the abdomen of a typical, normal, living male (fig. 3).

> The abdomen more distinctly petiolate; obovate, widest at the third segment; segments two and three subequal, long, the second longer, together occupying about half the surface; the caudal margin of segment two concavely curved in the dorsal aspect; the fourth, fifth, sixth, and seventh segments subequal, segment four about half

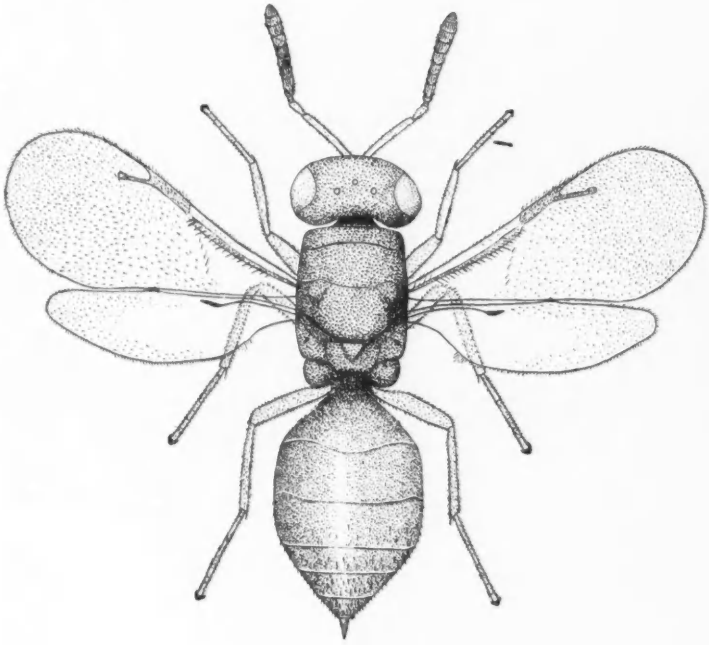


FIG. 1

FIG. 2

FIG. 3

FIG. 4

Fig. 1. Adult female *Pachycrepoideus dubius* Ashmead. Abdomen typical of living parasite. Dorsal aspect.
Fig. 2. Abdomen of dried female. Dorsal aspect.
Fig. 3. Abdomen of normal living male. Dorsal aspect.
Fig. 4. Abdomen of dried male. Dorsal aspect.

the length of segment two, the other segments successively slightly shorter; segment eight acute and apical; abdomen moderately concave dorsad, decidedly convex ventrad.

Egg. The egg (fig. 5) is elongate, cylindrical, opaque white with a smooth surface which on high magnification presents a fine sculpturing. Though subject to some variation the egg is usually strongly convex dorsally and faintly convex or flat ventrally, and when viewed dorsally is obovoid in shape, the cephalic end being the larger. The ends are rounded. At deposition the egg averages 0.29 mm. in length, and 0.10 mm. at its greatest width.

First-instar Larva. The first-instar larva (fig. 6), freshly hatched, averages 0.28 mm. in length and 0.10 mm. at its greatest width. The size varies slightly and depends largely on the size of the egg, the larva always being slightly less than the egg in length. In color it is translucent, except for an elongate, median, opaque zone which owes its opaqueness to the presence of food particles in the alimentary tract. The form is that of a planidium larva. It consists of a prominent head and thirteen body segments, the prothoracic or first segment being slightly the widest and the remaining segments narrowing posteriorly. Dorsally and laterally each segment, except the apical, bears two pairs of small setae which decrease in size posteriorly and are arranged as shown in figure 6. In addition, encircling the anterior border of each segment is a series of minute spines, visible only under very high magnification.

The head is more or less semicircular in outline and is superficially inserted in the prothorax. It measures 0.093 mm. in width and is similar to the body in color, but slightly more heavily chitinized. Anteriorly it bears a pair of small truncate antennae. On the ventral surface of the head (fig. 7) are three pairs of long setae, one pair immediately in front of the mouth and two pairs lateral to the mouth. The mouthparts are anterio-ventral and surrounded by a short tubular structure formed from the integument, this being quite conspicuous when the larva elevates its head. The mandibles (figs. 10 and 11) are relatively long, narrow, slightly curved, deep amber in color and lie in the preoral cavity. They average 0.0125 mm. in length. Supporting the mandibles and encircling the preoral cavity are the thickened ventral margins of the epicranium[1] which form a rather striking feature of the front of the head, but are visible only in cleared specimens (fig. 10). The lateral epicranial margin, or pleurostoma, on either side of the preoral cavity produces at its anterior or dorsal extremity the superior pleurostomal ramus. This ramus articulates with the mandibular acron, the upper basal portion of the mandible which is provided with a slight depression or concavity. A similar branch, the inferior pleurostomal ramus, is given off at the posterior or ventral extremity of the pleurostoma and bears a deep socket, the glenoid fossa, in which the relatively large mandibular condyle articulates. The inferior pleurostomal rami are united by a short concavely-curved chitinized rod and thus present the appearance of a continuous band passing below the preoral cavity and

[1]Terminology after Vance and Smith (1933).

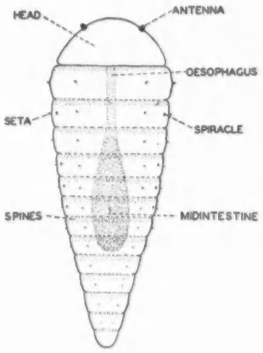


FIG. 6

FIG. 5

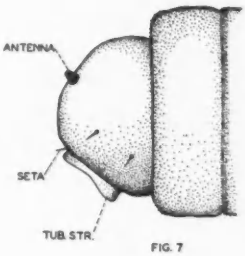


FIG. 7

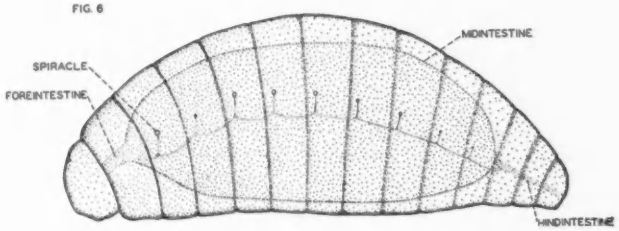


FIG. 8

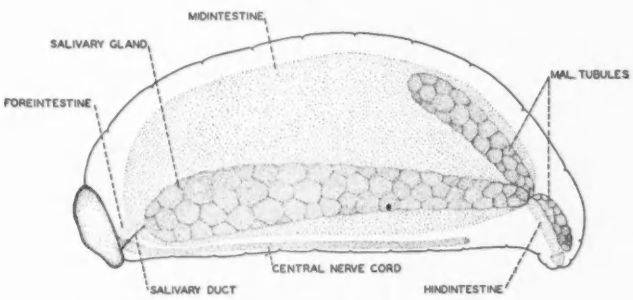


FIG. 9

Fig. 5. Egg of *Pachycrepoideus dubius*. Lateral view.
Fig. 6. Freshly-hatched first-instar larva Dorsal view.
Fig. 7. Head of first-instar larva showing. tubular structure (TUB. STR.) surrounding the mouth-parts. Lateral view.
Fig. 8. Third-instar larva. Lateral view.
Fig. 9. Fifth-instar or mature larva. Fat body removed to show internal structures. Lateral view.

connecting the posterior extremities of the pleurostomata. That portion of the epicranial margin which begins at the posterior extremity of the pleurostoma and extends below and laterad to the preoral cavity is termed the hypostoma. The hypostomata diverge slightly as they proceed posteriorly. The posterior extremities of the hypostomata are united by a long semicircular band of chitin, the tentorium, which extends dorsocaudad well into the prothorax. The epistoma, or the epicranial margin above the mouth, begins near the base of the superior pleurostomal ramus and extends over the preoral cavity to a similar point on the other side. The epistoma bears the two head setae just anterior to the tubular structure surrounding the mouth parts and defines the labrum dorsally. The labrum bears three pairs of minute papillae.

The alimentary canal is only vaguely discernible through the transparent cuticle, except for the midintestine which appears as an elongate, median, opaque area due to the presence within the midgut of whitish food material. From a narrow oesophagus extending through the prothoracic segment, the canal gradually widens into a rounded sack-like midintestine which terminates in the region of the seventh abdominal segment. Only a short proctodaeal invagination was discernible.

The tracheal system is composed of the usual lateral longitudinal trunks united anteriorly in the prothoracic and posteriorly in the eighth abdominal segment by transverse commissures. Extensions of the longitudinal trunks pass anteriorly and posteriorly into the head and the caudal abdominal segments. There are four pairs of spiracles, one pair situated on the second thoracic segment and one on each of the first three abdominal segments.

Considerable growth is attained by the first-instar larva before molting. The full-grown first-instar larva averages approximately 0.45 mm. in length and 0.19 mm. in width. The larva is now widest at the second abdominal segment and tapers gradually toward either end, presenting a more or less fusiform appearance. The midintestine has increased considerably in size and now occupies about two-thirds of the body cavity.

Second-instar Larva. The resemblance between the second-instar larva and the full-grown first-instar larva is marked. The second instar, however, is slightly arched dorsally as opposed to the straight dorsum of the first instar. The appearance of the second instar may be described as a cloudy translucense, except for a large, median, ovoid area which is opaque white, this area owing its color to the presence of whitish food in the alimentary tract.

The head measures 0.12 mm. in width and is much less conspicuous than in the preceding instar. Anteriorly it bears a pair of minute papilliform antennae. The tubular structure surrounding the mouthparts and the prominent head setae of the first instar are absent. The mandibles are almost straight with sharp, heavily chitinized tips. They average 0.0187 mm. in length. The angle of divergence between the hypostomata has increased with a resultant increase in the width of the tentorium which is now almost as wide as it is long. The base of the tentorium has become flattened, forming a distinct tentorial bridge.

The arrangement of the sensillae around the preoral cavity is similar to that of the fifth instar or mature larva.

There are nine pairs of spiracles, one on each of the body segments two to ten inclusive; those on segments two, four, five and six being larger. The spiracles on segments three, nine and ten appear to be nonfunctional as the spiracular trunks lack the characteristic silvery appearance of tracheae filled with air.

Dorsal and lateral spines are present on all the body segments while ventral spines appear on only the first three. Narrow bands of minute spines encircle the borders of all the body segments, save the anterior border of the prothoracic segment.

The mature second-instar larva averages 0.54 mm. in length and 0.24 mm. at its greatest width.

Third-instar Larva. The third-instar larva (fig. 8) varies from a faint grayish to a pale tan color, depending largely on the state of decomposition of the host on which the larva has been feeding. The form is broadly spindle-shaped, the cephalic end being somewhat blunt. The dorsum is moderately arched. The arrangement of the setae and spines on the body segments is similar to that of the second instar.

The head measures 0.19 mm. in width and bears anteriorly a pair of minute papilliform antennae. The mandibles resemble those of the second instar and average 0.025 mm. in length. The angle of divergence between the hypostomata has again increased so that the tentorium is now slightly wider than long. The tentorial bridge appears to lie just within the prothoracic segment.

The midintestine is greatly distended and occupies approximately three-fourths of the abdominal cavity. Surrounding the midintestine are numerous adipocyts which are only vaguely discernible and appear to contain large numbers of oil globules.

There are nine pairs of functional spiracles. The spiracles on segments two, four, five and six are slightly larger than those on segments seven and eight, while those on segments three, nine and ten are slightly smaller.

The mature third-instar larva averages 0.77 mm. in length and 0.36 mm. at the greatest width.

Fourth-instar Larva. In most respects the fourth-instar larva is merely a larger edition of the third-instar larva. The color, however, is a dilute milky white.

The head measures 0.245 mm. in width; the mandible averages 0.035 mm. in length. The tentorium has again become wider in proportion to its length, representing an intermediate stage between that of the third instar and the fifth instar or mature larva. The sensory papillae about the preoral cavity have the same arrangement as those of the mature larva.

The mature fourth-instar larva averages 1.17 mm. in length and 0.53 mm. at its greatest width.

Fifth-instar Larva. The fifth-instar or mature larva (fig. 9) is grayish white in color, except for a darkish elongate, median, dorsal area occupied by the heart. The heart itself is translucent, but the brownish alimentation in the midintestine which lies directly below the heart

gives this area a dark appearance. The mature larva is elongate, cylindrical, and tapers gradually in width toward either end, the cephalic end being somewhat more blunt than the apical. The body is decidedly arched dorsally and consists of thirteen segments, the apical segment being dorso-ventrally bilobed. Small dorsal, lateral, and ventral setae are present on all the body segments. The prothoracic segment bears on either pleural area a circular group of numerous sensory papillae.

The head is roughly semi-circular in outline and measures 0.35 mm. in width. Anteriorly it bears a pair of small hemispherical antennal foramina from which project a pair of small rod-shaped antennae. The mouthparts are ventral and located on a slight protuberance. The mandibles (fig. 12) are large and triangular in outline with heavily chitinized and pigmented tips. They average 0.05 mm. in length. The configuration of the combined epistoma, pleurostomata and hypostomata of the mature larva (fig. 13) presents a marked difference to that of the primary larva or first instar (fig. 10). The pleurostomata are now slightly anterior to the preoral cavity and oblique in position. The pleurostomal rami project posteriorly mesad to the mandibles, the inferior pleurostomal rami being relatively long. The hypostomata, together with the pleurostomata, form on either side of the preoral cavity conspicuous linear bands which extend latero-ventrad from the posterior extremities of the epistoma. The caudal ends of the hypostomata are widely separated. The tentorium extends dorso-caudad, the tentorial bridge lying just within the prothoracic segment. The width of the tentorium is twice the apparent length. There are four pairs of sensory papillae above the preoral cavity on the labrum, six pairs lateral to and one pair below the preoral cavity.

Beginning at the mouth the oesophagus extends ventral to the tentorial bridge well into the prothoracic segment and joins the midintestine which rapidly widens to form a huge globular sac occupying the greater part of the body cavity (fig. 9). The midintestine, which appears light brown in color due to the contained fecal material, abruptly constricts in the region of the tenth body segment where it joins the narrow tubular hindintestine. Attached to the anterior extremity of the hindintestine are three malpighian tubules, two extending anterio-dorsad on either side of the midintestine above the salivary glands while the remaining one is shorter and projects caudad immediately dorsal to the hindintestine. The hindintestine terminates caudally in a short, bulbous structure which probably is a composite of the anal aperture and its associated sphincter muscles. Extending along and closely appressing either side of the midintestine are a pair of elongate, very well developed salivary glands which terminate at the posterior end of the midintestine. Anteriorly in the region of the prothoracic segment they are joined by a pair of fine salivary ducts which coalesce ventral to the oesophagus to form a short, median, common salivary duct that terminates in a slight bulbous enlargement at the ventral edge of the preoral cavity. The heart lies immediately below the integument along the dorsal median line but being translucent, is extremely difficult to observe. It is detected by its rhythmic contractions which averaged twenty-two contractions per minute for five mature larvae. Surrounding the

internal organs, except the heart, and completely obscuring them is a dense layer of adipocyts. These are white in color except for scattered, small, darkish spherical areas, presumably globules of oil. More or less embedded in the ventral portion of the fat body is the central nerve cord which extends caudally to approximately the tenth body segment.

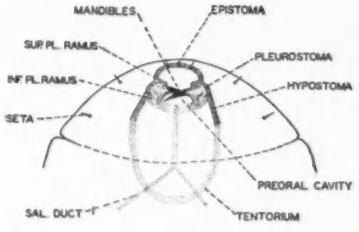


FIG. 10

FIG. 11

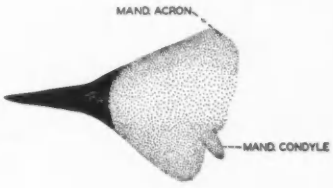


FIG. 12

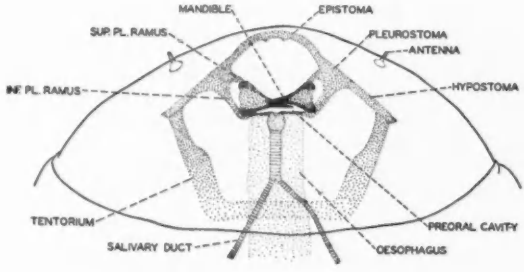


FIG. 13

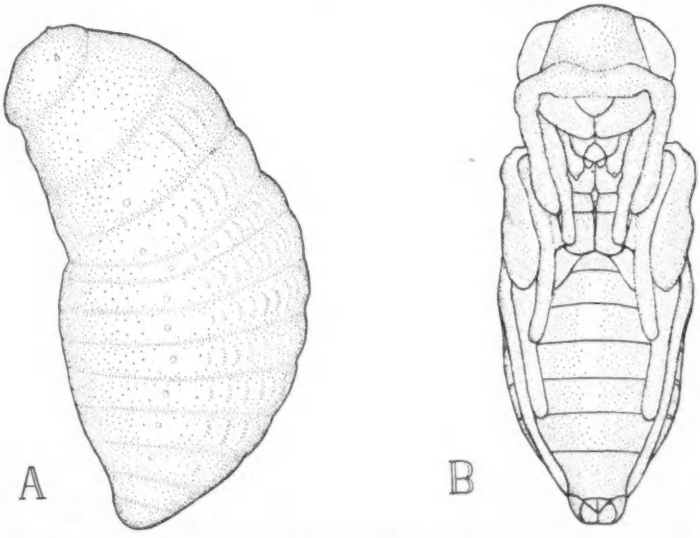
Fig. 10. Head of first-instar larva. Cleared specimen. Ventral view.
Fig. 11. Mandible of first-instar larva.
Fig. 12. Mandible of fifth-instar larva.
Fig. 13. Head of fifth-instar larva. Cleared specimen. Ventral view.
Figs. 11 and 12 drawn to same scale.

Anteriorly it is connected to the brain by a pair of circumoesophagal connectives.

The tracheal system is well developed, tracheal branches from the longitudinal trunks ramifying profusely to all parts of the body. There

are nine pairs of functional spiracles, one on each of the body segments two to ten inclusive. The spiracles on the second segment are the largest, measuring 0.025 mm. in diameter, while those on segments three, nine and ten are the smallest, measuring 0.016 mm. in diameter. A tenth spiracular trunk apparently extends to the integument, but it lacks a distinct spiracular opening.

Imaginal discs are discernible only in preserved specimens. Three pairs of elongate discs in the ventral portion of the thoracic region represent the immature legs while two pairs in the pleural areas of segments two and three represent the developing wings. The developing external genital organs of the female are represented by a pair of ventral imaginal discs in each of the segments ten, eleven, and twelve; those of the male by a ventral pair in segment twelve. The mature fifth-instar larva averages 2.0 mm. in length and 0.9 mm. in width.



Text figs. A and B. A, Prepupa, lateral view. B, Pupa, ventral view, female.

Prepupa. The voidance of the larval "meconium" and the attainment of the prepupal stage is accompanied by a marked decrease in size. The prepupa averages 1.5 mm. in length and 0.8 mm. in width—an average decrease in length of 0.5 mm. and in width of 0.1 mm.

The prepupa (fig. A) is ivory white and differentiated into two distinct regions, a relatively narrow anterior region and a wider, ovoid, posterior region which corresponds to the abdomen. The head, though identical to that of the previous stage, is more conspicuous and relatively wider in comparison to the thoracic segments. The thorax is narrow and cylindrical, the segments being subequal in width. The prothoracic

segment is longest, gradually tapers toward the head and bears on either side a circular group of numerous sensory papillae. The abdomen is ovoid and slightly longer than the combined head and thorax. The first abdominal segment is very short, especially the ventral portion. The integument is highly wrinkled, particularly in the dorsal aspect, and presents a shrunken appearance.

Pupa. The pupa (fig. B) is of the typical naked chalcid type. A curious feature, however, is the presence of a cushion composed of numerous moderately long bristles on the vertex of the head, yet the corresponding area on the larval or adult head is bare. The size varies considerable and depends on the size of the host, the conditions of superparasitism, and the sex of the individual. Female pupae, reared on *Piophila casei* and in the absence of superparasitism, average 2.0 mm. in length and 0.74 mm. in width; males average 1.65 mm. in length and 0.60 mm. in width.

The newly-formed pupa is entirely white. In about two days the first pigmentation appears. The eyes and ocelli take on a pinkish caste and in another day become bright red. Coincident with these changes, the color of the pupa progresses through a cream to a light tan. At this stage in the color development of the pupa the divisions along which the theca splits during adult emergence show up clearly as white lines. These remain in evidence until the adult emerges, but become less discernible with the appearance of the dark adult colorations.

As time for emergence approaches the dark adult colorations appear. The eyes and ocelli change to a reddish brown while the body and head become blackish.

BIOLOGY

Egg Stage. After deposition the egg is homogeneous in content and color, and for several hours there is no apparent change in its appearance. As development continues, however, the chorion loses much of its opaqueness and an elongate irregular mass of dense protoplasmic material is faintly discernible in the central region of the egg. Three to four hours prior to hatching the outlines of the embryo, which at this stage resembles the freshly-hatched first-instar larva, are faintly visible. It is observed to be slightly shorter than the egg in length, a small area at both the anterior and posterior poles being quite clear and translucent. In the region of the cephalic pole the chorion tends to shrivel slightly and presents a nipple-like appearance. Immediately preceding eclosion segmentation and body armature are distinctly visible through the now transparent chorion and the mature embryo can be seen contracting and twisting within the egg.

Eclosion of the larva is effected through a transverse slit made with the mandibles in the wall of the chorion near the cephalic end. Through this aperture the tubular structure surrounding the mouth parts is forced out and the larva then proceeds to exert pressure against the opening until the chorion mechanically tears sufficiently to permit the escape of the larva. The collapsed egg shells persist and are frequently found attached to the host pupal remains or the inner surface of the host puparium.

In the laboratory, the incubation period of the egg varied from twelve to twenty hours.

Larval Stage. The newly-hatched larva does not begin to feed immediately after eclosion, but crawls more or less haphazardly over the host pupa for a variable period of time attacking and destroying any eggs or other larvae which it encounters. After two to three hours the larva ceases its crawling activities, pierces with its mandibles the host integument and begins feeding by sucking out the fluid contents of the host which apparently is killed at this time.

The feeding habits of the larval stages are subject to considerable variation. The primary larva normally changes its feeding position several times prior to the first ecdysis, while the second, third, and fourth stage larvae tend to remain in one position. On the other hand, the larva may remain at the original feeding puncture during the greater part of the larval period. The maturing fifth stage larva commonly changes its feeding position many times during the last day prior to the quiescent period preceding the change to the prepupal condition.

During moulting periods the larva temporarily ceases to feed. Moulting is effected in the usual manner, the larval skin splitting anteriorly and being slowly worked back over the body segments. Feeding may be resumed before the exuvium has passed off the posterior body segments. The exuvium or cast skin is extremely delicate and difficult to distinguish.

Throughout larval life no fecal material is voided, it being retained in the midintestine until after the larva has reached maturity. Several times, however, maturing larvae have been observed to void clear drops of liquid from the anus, indicating the presence of an anal aperture during the late larval stages.

The length of the larval period in the laboratory averaged nine days. The average time spent in each larval stage was as follows:

First stage	2½	days
Second stage	1	day
Third stage	1	day
Fourth stage	1	day
Fifth stage	3½	days
Total	9	days

The time spent in the various larval stages and length of the larval period varied somewhat but the above figures represent the averages obtained from data gathered throughout the entire period of investigation.

Prepupal Stage. After maturing, the full grown larva ceases to feed and becomes quiescent, the only visible signs of life being the peristaltic waves passing along the midintestine. Some hours after feeding activities have ceased, the passage from the mid- to the hind-intestine opens and the larva begins to void considerable quantities of brownish, semi-liquid waste matter. As it does so, it diminishes appreciably in size and becomes lighter in color. The excretion of this fecal material requires from twenty to thirty minutes and is accomplished by peristaltic action.

Following the evacuation of the larval "meconium," a gradual change in appearance takes place and in six to seven hours the prepupal form is definitely attained, being quite white and immobile. A few hours prior to the fifth ecdysis, the general outline of the pupa is discernible through the prepupal integument.

There is no cocoon formed.

The prepupal stage had a duration in the laboratory of from twenty-four to thirty-six hours.

Pupal Stage. The fifth and final ecdysis takes place in situ, the larval "meconium" and remains of the host serving as a ventral cushion upon which the pupa rests. Moulting is effected through a median dorsal split in the prepupal skin over the thorax; the exuvium is then forced backwards over the body and is finally left between the caudal end of the newly-formed pupa and the larval "meconium."

The color changes through which the pupal stage progresses have already been described.

The day prior to adult emergence movements of the adult appendages can be seen through the transparent pupal covering.

The duration of the pupal stage varied from six to nine days, the duration of the pupal stage of the male being shorter than that of the female.

EMERGENCE

Emergence of the adult parasite is effected through a longitudinal median, dorsal split in the theca over the thorax and a transverse break which follows along the occipital foraminal impression, down the posterior margins of the eyes, and across the clypeal region. The cephalic portion of the pupal skin covering the head capsule and antennae, except for the mouth parts, breaks away and remains intact over the head of the adult while the main body of the pupal case is worked off posteriorly. When free of the posterior portion of the theca, the adult scrapes off, with the forelegs, the cephalic covering, except for the antennal sheaths. This covering splits along very definite cleavage furrows evident as white lines on pupae which have not attained the dark adult coloration. The cephalic covering is usually removed before the adult issues from the host puparium, but occasionally parasites have issued from the host with this covering still intact. A small meconium is voided by the adult immediately prior to emergence from the pupal case.

After emergence from the theca has been effected and while still within the host puparium, the adult becomes inactive for a few hours. When ready to issue from the host puparium, the adult bites or gnaws a roughly-circular hole in the puparium and squirms through the opening. The antennal sheaths, which are still intact, are pulled off with the forelegs immediately after the adult has issued. The exit hole usually occurs in the dorsal half of the puparium and toward one of the two ends—most frequently the anterior.

The parasites usually issue from the host puparia early in the morning. Males issue a few hours to a day prior to the issuance of the females.

LENGTH OF LIFE CYCLE

During the winter months when the room temperature in the laboratory was more or less constant the average length of the life cycle of the parasite reared on *Piophila casei* was 17.5 days for males and 18.5 days for females, with a minimum of 15 days (two instances) and a maximum of 23 days. All individuals which emerged on the fifteenth and sixteenth days were males, the shorter life cycle in the male being largely accounted for by the shorter pupal period.

In an individual with a life cycle of 18.5 days the time spent in the various stages was as follows:

Egg stage	1.0 days
Larval stage	9.0 days
Prepupal stage	1.0 days
Pupal stage	7.5 days
Total	18.5 days

The average length of the life cycle in the laboratory of *Piophila casei* Linn. cultured on smoked ham averaged eighteen days with a minimum of fifteen and one half days.

COPULATION

Males usually emerge before the females, the actual time varies from a few hours to a whole day. Copulation, therefore, usually occurs almost immediately after the female emerges. The male is sexually the more active. When coming into proximity with a female, the male raises his wings and immediately seeks to mount. The female apparently attempts to avoid copulation but, if unfertilized, this resistance is usually overcome. Before the male effects copulation, however, he "woos" the female. The "wooing" is done by placing the antennae between those of the female and vibrating them rapidly in a latero-caudad direction as if stroking the ventral surface of the antennae of the female, but actual contacts, if any, are few and momentary. The female responds by raising the flagella of the antennae to an upright position and lowering the anterior sternites of the abdomen so that the genitalia face caudad, thus permitting the male access to the genital aperture. This "wooing" process may continue for ten to fifteen seconds after which the male moves quickly backward, bending the tip of the abdomen below that of the female, and fertilization is accomplished, the actual contact lasting but one or two seconds. Should the male fail to make the proper connection, the "wooing" process is again reverted to before each subsequent attempt to fertilize the female. Once a female is fertilized no second copulation is permitted. Aspiring males, if they succeed in mounting, are dislodged by the posterior legs of the female.

It is advisable to segregate the sexes shortly after copulation is accomplished. Unless this is done, fertilized females are constantly confronted with the necessity of avoiding a second copulation and, if this condition is allowed to continue indefinitely, not only are oviposition activities considerably curtailed but the length of life of the female is shortened. To avoid this difficulty, the sexes were separated after a twenty-four hour period.

OVIPOSITION

P. dubius attacks its host only after the puparium is formed, it does not react to motile larvae. Puparia of *Piophila casei* have been successfully parasitized as early as seven hours after formation, while the host is in the prepupal stage, and as late as approximately eighteen hours of emergence of the adult. In the laboratory the prepupal stage of *Piophila casei* has a duration of twelve to eighteen hours, the pupal stage five to seven days. Though ordinarily considered a pupal parasite, *P. dubius* will attack host puparia containing the prepupal stage even as early as an hour and a half after the formation of the puparium. A decided preference, however, is shown for the older host puparia in which the pupal stage has been attained. Females were induced to attack puparia and oviposit in those containing the prepupal stage only when other older puparia were not available.

Oviposition activities do not appear to be confined to any particular portion of the day but seem to be largely a matter of individual activity on the part of the female. Temperatures being favorable, some females may be observed ovipositing at any daylight hour, others will be resting inactive on the sides of the cage. Activity is more pronounced, however, in the morning when the sun is shining in the windows of the laboratory, which faces east, and the light intensity is high. The parasites are usually inactive at night. Artificial light, however, stimulates oviposition and with its use females may be induced to continue their ovipositional activities at night.

In preparing to oviposit the female explores the host puparium by rapidly touching or tapping its surface with the extreme tips of her antennae. When a suitable place is discovered, the female assumes a somewhat upright position, brings the tip of the abdomen forward, and places the ovipositor at the desired spot by feeling the surface with the tactile extremities of the ovipositor sheaths. After the ovipositor is oriented, the tip of the abdomen is returned to about its normal position. The act of forcing the ovipositor through the puparium usually requires from a few to several minutes. One instance was recorded in which a little more than sixteen minutes elapsed before the female was successful. After the puparium has been punctured, the female may immediately deposit an egg or she may pierce the pupa, ostensibly to feed on the exudation of host body fluid resulting from the wound. During oviposition, the ovipositor is inserted to its full length several times and in various directions, between the pupa and the old prepupal skin which lines the interior of the puparium, as if providing a free space for the egg. The egg is deposited externally on the pupa, usually lateral to the position of the parasite, the actual deposition requiring but a few seconds. On several occasions the actual expulsion of the egg from the ovipositor was observed, the process being comparable to the formation of a drop of liquid at the end of a hypodermic needle. The ovipositor is immediately withdrawn after egg deposition. The tip of the abdomen may or may not be brought forward to receive it and to prod the oviposition puncture as though sealing it. Oviposition may occur at any point on the puparium, inter- or intrasegmentally.

A female may oviposit successively in a single host regardless of the fact that the latter may be in actual contact with several unparasitized puparia. One female was observed to oviposit five times in a puparium before passing on to examine one of several unparasitized hosts in the immediate vicinity.

Oviposition activities may begin an hour after issuance of the female from the host puparium and usually continues intermittently until a day or two preceding death.

HABITS OF THE ADULTS

The adult is very active and capable of sustained flight. Individuals of each sex have been observed to remain in flight in the laboratory for periods of ten minutes or longer, directional flight often being interspersed by short intervals of hovering. Adults crawling on a horizontal surface, if suddenly touched with any instrument, will not take flight but instead hop a short distance and on alighting will remain perfectly motionless for a brief period and then resume their crawling activities. The adult is usually inactive at night.

Both sexes are positively phototropic, particularly to natural light. However, when in the presence of the host material from which the parasites are emerging, the females respond more readily to light than the males, the males tending to remain with the host puparia. Advantage is taken of this characteristic in segregating the sexes. Artificial ultra violet light to all appearances is just as effective as natural light in stimulating phototropic responses. Response to ordinary artificial light is much less marked, males tend to remain more or less inactive while females, though they do not respond phototropically, will resume oviposition activities.

Both sexes feed readily on moistened raisins and sweetened solutions. In addition females, after puncturing the host puparium as though to oviposit, commonly pierce the host pupa with the ovipositor and feed on the body fluids of the host exuding from the wound.

The length of life of the adult varies considerably and is influenced by several factors. When provided only with moistened raisins and kept in separate vials the average length of life of 204 males was 18.3 days with a minimum of 3 days and a maximum of 61 days while that of 149 females was 17.6 days with a minimum of 4 days and maximum of 51 days. The periodical provision of dilute honey or host puparia, in addition to the moistened raisin, greatly prolonged the life of the female. The number of individuals in a vial had no appreciable effect on their longevity, provided they were of the same sex. However, when both sexes are confined in the same vial the average length of life of the male is only slightly shortened while that of the female is very decidedly shortened.

SEX RATIO

The general sex ratio under laboratory conditions was determined by retaining and sexing all the adults which emerged in the stock culture tubes for three successive generations. Of the 1292 individuals sexed,

761 were females and 531 males, showing a general predominance of females in the ratio of almost one and one-half to one.

Certain factors may operate to influence the sex ratio. Perhaps the most important of these factors is lack of fertilization of the female resulting in parthenogenetic reproduction with the consequent production of an all male progeny. The species is arrhenotokous. Fertilization if delayed five days or longer also results in a progeny consisting of all males. Unfertilized females five or more days old do not respond to the advances of the males and will not permit copulation. Excessive superparasitism may also have some effect on the sex ratio. It seemed that host puparia which were permitted to remain with female parasites for long periods and were subject to excessively heavy parasitism produced a preponderance of males.

SUPERPARASITISM

In the laboratory superparasitism was of common occurrence. Dissections of parasitized hosts frequently revealed the presence of two or more parasite eggs. In one instance the chorions of twenty-six eggs were found within a single puparium.

Supernumerary parasitism ordinarily results in only one of the parasites completing its development and emerging as an adult. That only a single individual survives can be explained if one considers the habits of the newly hatched first-instar larva. After eclosion the larva does not immediately begin to feed upon the host tissue, but crawls actively over the host for some time destroying any egg or other larvae which it encounters. An encounter between two larvae invariably results in only one survivor—there is no compromise. The more active or more recently hatched larva is usually the survivor. The wanderings of newly hatched larvae over the host are somewhat haphazard as is evidenced by the fact that occasionally two parasites complete their development on a single host and emerge as adults, indicating that an encounter between the larvae never occurred.

It is generally known that superparasitism among parasitic *Hymenoptera* may often result in the loss of all the parasites on a given host through lack of sufficient food to support the development of the parasites. The loss of all *P. dubius* larvae on a given host has not been observed to occur in the laboratory, one of the larvae invariably surviving. The larva of *P. dubius* may develop and complete its life cycle on full grown larvae, prepupae, and pupae of its own species. This ability of the larva in conjunction with the pugnacious characteristics of the newly hatched larva it seems is a plausible explanation of why superparasitism in the case of *P. dubius* does not result in the loss of all the parasites on a given host.

It is quite probable that superparasitism also exists under natural conditions. On a number of occasions females in the laboratory have been observed to oviposit successively two to five times on one host before moving on to examine other host puparia in the immediate vicinity. It seems reasonable to assume, then, that such behavior would also occur in the field.

MULTIPARASITISM

The relationships existing between *Pachycrepoideus dubius* and other parasites of dipterous puparia are little known.

In their observations on the parasites of *Ceratitis capitata* Wied. in Hawaii Pemberton and Willard (1918) note that *P. dubius* was invariably intrinsically superior to the other hymenopterous parasites. This superiority of *P. dubius* may undoubtedly be attributed to the apparent advantages of the external position of *P. dubius* on the host with respect to the internal position of the other parasites.

On certain of its hosts in the laboratory *P. dubius* proved a weak competitor to *Muscidifurax raptor* Gir. and Sand., another external parasite of dipterous pupae, under conditions in which equal numbers of females of each species were confined simultaneously with the host puparia for a limited period of time.

HYPERPARASITISM

Pachycrepoideus dubius is a true hyperparasite only in so far as it attacks those *Diptera* which in themselves are primary parasites. There is only one record of such in the literature. Jaynes (1930) observed *P. dubius* attacking puparia of *Paratheresia claripalpis* van der Wulp which is a dexiid parasite of *Diatraea* in Argentina. In the laboratory *P. dubius* readily attacked and successfully parasitized *Trichopoda pennipes* F., a tachinid parasite of *Anasa tristis* DeGeer and an undetermined tachinid parasite of *telea polyphemus* Cramer.

There are no known primary parasites of *P. dubius*.

MASS PRODUCTION

The ease with which the parasite may be handled and reared under laboratory conditions suggests a high degree of adaptability, on the part of the parasite, to methods of mass production. Given an abundance of host material, it is the writer's belief that unlimited numbers of *P. dubius* could be reared with little ado. Nor should the production of a large and continuous supply of host puparia present any difficulties. Methods for the mass production of several hosts of *P. dubius* have already been worked out, namely: *Musca domestica* Linn., *Phormia regina* Meig., *Lucilia sericata* Meig., *Drosophila melanogaster* Meig., and *Piophila casei* L. (a method for the mass production of which has been worked out by the writer (1938)).

Fullaway (1914) in his work on parasites of the horn fly in Hawaii has already demonstrated the feasibility of propagating *P. dubius* in large numbers. Information, however, on the host used or methods employed could not be found.

Some observations have been made which indicate the possibility of rearing *P. dubius* on an artificial medium. On a number of occasions, in the stock culture vials, parasite eggs have been found which were deposited external to the puparium, in contrast to the usual internal position. Moreover, females have been induced to oviposit, though apparently somewhat restrainedly, externally on host pupae which have been dissected out of the puparium. It would seem, then, that the oviposition

habits of the female are not rigid, but may be adapted to varied conditions.

It will be recalled that the host is killed by the parasite larva shortly after its eclosion, the larva then feeds as a scavenger. Newly-hatched larvae placed on dead hosts in which decomposition of the body tissues is well advanced develop rapidly, indeed apparently more rapidly than similar larvae placed on living or recently killed hosts. The development of an artificial substitute for such a substrate should present fewer difficulties than a substitute for living organic matter. The fact that the parasite is facultative and the larval stage external would tend to simplify the problem.

In the development of an artificial medium fungus growths on the substrate must be prevented since the larval stage of *P. dubius* is relatively easily overwhelmed by them.

SUMMARY

The genus *Pachycrepoideus* Ashmead, which belongs to the chalcidoid family *Pteromalidae* and the subfamily *Sphegigasterinae*, was originally described in 1904 by Ashmead who named *Pachycrepoideus dubius* Ashmead as type, but failed to describe the species or even indicate it was new to science. In 1910 Girault and Sanders redescribed the genus, describing *Pachycrepoideus dubius* Ashmead, sp. nov. and designating it as the type species of the genus.

Certain taxonomic discrepancies which exist in Girault and Sanders' description of the species are pointed out.

P. dubius is a primary parasite of the common cheese skipper, *Piophila casei* Linne. It attacks the host in the pupal stage.

The egg is deposited on the pupa within the puparium, the larva shortly after eclosion killing the host and feeding externally (to the pupa within the puparium) as a scavenger.

It was found that the parasite could pass through its entire life cycle on host pupae dissected out of the puparium and in this way it was possible to make detailed observations on all phases of its development.

There are five larval instars and a well-marked prepupal period. No cocoon is formed.

In the laboratory the incubation period of the egg varied from 12 to 20 hours, the larval period varied from 8 to 10 days, the prepupal period from 1.0 to 1.5 days, and the pupal period from 6 to 9 days. The life cycle averaged 17.5 days for males and 18.5 days for females.

The life cycle of the host, *Piophila casei*, cultured in the laboratory on smoked ham averaged 18.0 days.

Males issue a few hours to a day prior to the issuance of the females.

Mating may occur immediately after issuance from the host and females may begin to oviposit within an hour. Once a female is fertilized no second copulation is permitted.

The species is arrhenotokous. Females if not fertilized within the first 5 days after issuance from the host puparium usually do not respond to the sex stimulus. The females predominate in the ratio of approximately 1.5 to 1.

The parasites are usually inactive at night. Artificial light, however, stimulates an ovipositional response.

The length of life of adults varies considerably under different conditions. When provided only with moistened raisins the males apparently live longer than the females. The periodical provision of a mixture of honey and water or host puparia prolonged the life of the female.

Females, after puncturing the puparium as though to oviposit, commonly pierce the host pupa and feed on the body fluids of the host exuding from the wound.

The eggs are laid singly but superparasitism is quite common, as many as twenty-six eggs having been found within a single host puparium.

Usually only one adult issues per host puparium, the first larva to hatch generally destroying the remaining eggs and larvae.

Occasionally two parasites were reared from a single host puparium.

The parasite is facultative in its host relationships and attacks numerous members of the suborder *Cyclorrhapha*.

On certain of its hosts in the laboratory *P. dubius* proved a weak competitor to *Muscidifurax raptor*.

P. dubius is a true hyperparasite only in so far as it attacks those *Diptera* which in themselves are primary parasites. There is only one record of such in the literature.

There are no known primary parasites of *P. dubius*.

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LIVING THINGS, HOW TO KNOW THEM, by H. E. JAQUES. Pages 1–164, 421 text figs. 5.5 x 8.75 inches. 1939. Published by H. E. JAQUES, Mt. Pleasant, Iowa. Price, spiral binding, $1.00; cloth binding, $1.80.

This is a synoptic and illustrated key covering the large groups of all plants and animals. It follows the general design of the author's earlier successful guide, "How to Know the Insects." We will be glad to see how this sells as compared with the sale of the insect guide which is a handy volume in identifying members in a more limited field. Our present reaction to this second guide is that the author is attempting to cover too much territory.—C. H. K.

BOOK NOTICES

202 COMMON HOUSEHOLD PESTS OF NORTH AMERICA by HUGO HARTNACK. Pages 1–310. More than 400 illustrations, 5½x8, semi-flexible Fabrikoid. 1939. Published by HARTNACK PUBLISHING CO., 608 S. Dearborn St., Chicago, Ill. Price $3.75.

Dr. Hugo Hartnack came to the United States from Germany in 1924. He is now one of the leading pest control operators in Chicago and recently became a member of the Entomological Society of America. He recognized the need for a book on American household pests and having given up hope that, let us say, Dr. E. A. Back would come to the rescue, he undertook to write the book himself, though English is not his mother language nor is entomology his profession. As such a project takes courage to start and will-power to complete, even without the handicaps besetting Dr. Hartnack, we feel that he deserves great praise for his accomplishment. There is danger that entomologists will approach a book by a pest control operator in an unsympathetic and hypercritical spirit. Dr. Hartnack anticipated his critics in a charming foreword confessing his faults and stating the points of view from which a fair judgment of the book should be made. He has succeeded in completely disarming his potential critics.

This book is refreshing in its unconventionality. It is not an impersonal textbook, but a personal document expressing the ideas and beliefs of Dr. Hartnack along with more conventional descriptions of household pests and their biology. Those who have met Dr. Hartnack know that he has a pungent, forceful personality, which is clearly revealed in his book. We like his explanation: "And why should every book be like a textbook? How good that we live where we can express all we think and do not first have to make sure that what we want to say might not produce a fateful frown on some important forehead. I have taken full advantage of this privilege."

The text of Dr. Hartnack's sermon is taken from the writings of Dr. L. O. Howard and is printed at the beginning and at the end of the book: "When the economic entomologist confronts an emergency problem, it is his duty to bring measurable relief as speedily as possible. At the same time he must begin studies looking forward to natural and therefore comparatively costless control." In spite of the fact that the accomplishment of this ideal would put Dr. Hartnack and other pest control operators out of business, he stresses prevention of insect infestations rather than chemical treatments for relief. He would have all new buildings designed to be rat-proof and termite-proof and would eliminate interior construction that makes shelters for bedbugs, cockroaches, carpet beetles, etc. He urges better sanitation and care in the storage of food and disposal of wastes. He believes that if man gives insects and rodents an opportunity to live with him at his expense, he has no one to blame but himself.

Dr. Hartnack makes a vigorous plea for research on household insect pests and points out that Federal and State entomologists are giving too little attention to this important field in proportion to the effort and money being expended on research on agricultural pests. We agree, but must point out that the situation is not quite so bad as Dr. Hartnack implies when he writes, "In the Bureau of Entomology under the jurisdiction of one research worker, falls the whole field of insects that affect man and animals." This quotation is a tribute to Dr. Back, who is professor at large to the pest control industry, but it neglects the personnel of the Division of Insects Affecting Man and Animals. Anyone who wants to know what a conscientious pest control operator thinks concerning the ways and means of improving the service and standards of this profession will be enlightened by this book.

The bulk of the book is devoted to the instruction of the reader in the recognition, biology, damaging effects, and control of household pests. Rodents and bats are discussed first, followed by birds (we wonder why the English sparrow and pigeons are convicted and not the starling). Insects, of course, are by far the largest group and occupy 220 pages. The classification used is that of Handlirsch.

Finally arthropods other than insects are discussed. We can hardly regard all the 202 species as "common household pests" inasmuch as all forms known to cause trouble in and about houses are included and some are certainly uncommon as household pests.

We could point out a number of errors of fact, but what book is free from errors? On the whole the facts in the book are well-founded and up-to-date. There is no other book in English that is confined to the field of the pest control operator and that is so suitable for "real estate dealers, architects, builders, property owners, exterminators and their employees [and] manufacturers . . ." As far as scientific facts are concerned, the entomological student may glean them just as well, or better, from text books of medical entomology, general economic entomology, monographs, etc., but he cannot afford to miss the stimulating point of view of this book nor the remarkable and generally excellent illustrations assembled from the German literature with which Dr. Hartnack is familiar and which most American students tend to avoid. German workers have been more active than our own entomologists in research on household insect pests, and Dr. Hartnack has made good use of their findings. For example, there is no better monograph on the bedbug than that of Heinrich Kemper, no more thorough work on clothes moths than that of E. Titschack.

Dr. Hartnack occasionally goes back to ancient and medieval times in the discussion of common pests and reproduces curious old illustrations; e. g., "Jack Black, Her Majesty's Ratcatcher," and some pages of "A Treatise of Buggs" by John Southall, 1730. These illustrations plus a number of quaint, miniature cartoons sprinkled liberally through the book will relieve the monotony of study for those unaccustomed to it. Another innovation is the insertion of inch and centimeter scales on the inside margin of many pages where dimensions of insects are given. A Fahrenheit-Centigrade scale is given along one margin.

Near the end of the book Dr. Hartnack lectures on the sin of using illustrations without acknowledgment. We are sorry to say that the illustrations in his own book are not specifically credited. Instead, he names in a footnote at the beginning of each section the workers whose illustrations and papers were used. One cannot tell which investigator is responsible for a given illustration. No citations to the literature are given, but workers responsible for certain statements are often named in the text. The index is full of curious hieroglyphics, a key to the meaning of which is given.

In one respect this book is disappointing to us. When we heard that Dr. Hartnack was writing a book, we hoped to find in it the results of his personal experience in chemical control, results that could be described only by a pest control operator who has combatted pests in all sorts of situations by various methods. Instead we find only the barest outlines of control measures. Composition, concentrations and application are not described, nor does the author evaluate methods critically. That he did not do so is understandable, because the book is intended to tell the public only enough for them to understand their pest problems and get good pest control service.

We could go on writing about this unconventional book for hours, for one cannot open it anywhere without finding something novel or unusual. It has both popular appeal and sound facts, and if any book can enlighten the public about household pests, this one should succeed.—F. L. C.

THE EVOLUTION OF GENETIC SYSTEMS, by C. D. DARLINGTON. 149 pp. and 26 figures. 1939. Publishers: Cambridge at THE UNIVERSITY PRESS and THE MACMILLAN CO., 60 Fifth Ave., New York. Price $2.75.

Many books have been written about the causes of evolution with but a nodding reference to chromosomes, a fact which may seem strange when it is at the same time admitted these structures constitute the physical basis of almost all genetic differences. The present book, one of a new series of Cambridge Biological Studies, is a treatise on evolution in which the chromosome is the center of interest. It brings together, integrates, and interprets from an evolutionary standpoint the maze of detail and diversity which cytologists have been uncovering in a

rapidly expanding list of plant and animal species. Much of heredity and evolution is readily intelligible under the basic premise that inheritance is particulate. But the additional fact that the particles are organized into linear groups, the chromosomes, is also seen to be of paramount importance, imposing as it does many interesting restrictions upon the agencies of evolution. In the opinion of the author, this "combination of the material basis with the evolutionary framework provides the only means of making sense of biology as a whole." Certainly this book should lend to its reader the conviction that he cannot profitably ignore the newer knowledge of cytogenetics in constructing his own philosophy of evolution.

Written in essay style, the volume consists of 21 short chapters. Their developmental arrangement is indicated by the chapter titles, which will also serve to suggest the comprehensive and philosophical outlook of the author: Premises of Genetics—The Substance of Heredity—Sexual Reproduction—Meiosis: Pairing and Crossing-Over—Meiosis: The Process of Assortment—Change of Quantity: Polyploidy—Change of Position—Hybrids: Diploid and Polyploid—Change of Proportion—The Atom of Genetics—Chromosome Mechanics—Genotypic Control—The Mechanism of Crossing-Over—The Biology of Recombination—The Pursuit of Hybridity—The Permanent Hybrid—The Evolution of Sex—Sterility: The Contradiction—Apomixis: The Escape—The Integration of the Cell—The Evolution of Heredity.

As is seen, the earlier chapters are concerned with the detailed structure and mechanics of chromosomes. Throughout this discussion the chromosome is portrayed not as a stationary morphological unit but as a dynamic system which is continually undergoing cycles of change. One is impressed by the wealth of meaning which the author is able to attach to even the most minute features of chromosome form and behavior. At first the evolutionary implications are only briefly hinted at, but as the story unfolds, more and more generalities are put forth. One must also admire the author's skill at the art of parcimony; when two or more phenomena are to be explained they are often economically brought within the scope of a single hypothesis.

The phenomenon of crossing-over, one of the author's own specialties, is shown to be one of the most significant factors in the evolution of genetic systems. As a mechanism of gene recombination, it is found to be intimately associated with such diverse topics as sterility, polyploidy, stabilization, heterosis, the localization of inert genes, and transformations of sex-chromosomes. In fact, "it governs . . . the character of every genetic unit from the gene to the species. It is the central fact of genetics. . . . Without crossing-over indeed sexual reproduction is meaningless."

Darlington's style is very concise and his expression quite "thick" in places, so that a careful reading is necessary in order that essential points in the argument will not be overlooked. The reader, however, will have no difficulty in distinguishing what is fact from what is theory. References to experimental research (much of which deals with insects) are carefully indicated by footnotes on each page. An extensive bibliography and index (features which are commonly missing in the essay type of book) are provided. Many of the notions presented in this sketch are probably presented for the first time. It should prove to be a stimulating review of cytology for the geneticist, or of genetics for the cytologist, or of both for the general biologist.—C. W. C.

EMBRYONIC DEVELOPMENT AND INDUCTION, by HANS SPEMANN. Pp. 1–401, 192 text figs. 1938. 6.25 x 9 inches. The twenty-sixth volume of the Silliman Memorial Lectures. Published by the YALE UNIVERSITY PRESS, New Haven, Conn. Price, $5.00.

This work is one of the long series of authoritative and impressive volumes for which scientists are grateful to the donors of the Silliman Memorial Lectures of Yale University. The fund for the annual series of lectures is a memorial from her children in memory of their mother, Mrs. Hepsa Ely Silliman. The small

gift of eighty thousand dollars has elicited and financed the publication of some of the most useful summary scientific volumes.

Professor Spemann, of the University of Freiburg, has trained more men in the techniques of experimental embryology than has any other teacher. He is the Doyen in this field and in 1935 was given the international honor of the Nobel Prize in medicine. For forty years his conclusions in the very complex and difficult field of embryology have been founded directly on experimental evidence. He has advanced no startling "Spemann theory," and in all his writings has cited other workers with full credit. The energies too frequently lost by the successful (?) in futile envy and in defence of the straw-man of personal credit, in Spemann's case, appear to have been deflected into the problems of experimental embryology. However, we may be over enthused by a volume which is thoroughly documented and on every page gives gracious credit to others.

To place a picture of the contents of this volume before the reader is an exceedingly difficult task. It is because the book is a review of structures and forces of such exceeding complexity that any expression honestly depicting them, as exposed by experiment, of necessity has to be vaguely or generally stated. The terms used are those labelling forces which are always variables and which may appear in the embryo in any level of force possible to the particular varying factor. After reading the precise statements of morphology or the exact formulae of applied science this work has an effect of elusiveness. The casual reader can easily feel that the ghost of a science is walking in the shadowy background of involved processes. Yet, as Spemann points out, the forces under consideration are as exactly stated as the experimental material warrants.

The discussion has been limited almost entirely to Anuran development as that has been largely the field of the author's research. Chapters I and II deal with normal development and early experimental work. Chapter III deals with the composite vertebrate eye, an organ with the retina from one embryonic area while the lens comes in from another area. IV. This chapter analyzes the process of induction. It shows how a retinal area of the embryo can "induce" the development of a lens in almost any piece of ectoderm which has been placed over it by the experimenting embryologist. This evidence separates the "action system," or retinal area, from the "reaction system," or the area of ectoderm which develops into a lens. V. The pattern in the early gastrula or "material determination," is accepted as having been laid down in the activated egg before the beginning of development. The embryologist's work is then with the action and reaction of parts in the further development of the embryo. VI. Potencies, which are the possibilities of development in any part. VII. Induction of a secondary embryo by an "organizer." Inductors of the second order, etc. VIII. A discussion of the influence of underlying mesoderm on the development of the neural plate. IX. The conceptions of "potency" and of "determination." X. Abnormal inductions. XI. The means of induction. XII. Time correlation. XIII. Regional determination. XIV. Complimentary and autonomous induction. XV. The embryonic field, an idea developed by others, the radical forms of which Spemann questions. Some of these theories verge on vitalism which Spemann has never accepted in any form. XVI. The gradient theory. The weak spots of Child's special gradient theory are pointed out. It cannot deal with the discontinuities found in embryological development. XVII. The problem of "wholeness." XVIII. Concluding remarks.

The one thing which stands out in the volume is Spemann's remarkable ability, which attains to the point of genius, of eliminating personal prejudices and desires in his interpretation of experimental operations. This applies also to his relation to other workers in his field. He gives credit even for minute details to previous workers. In reviewing the present summary of experimental embryology one suddenly faces the fact that the author is neither directly nor indirectly and more subtly making an attempt to build up a personal reputation. "Embryonic Development and Induction" is a clear summary of the discoveries in experimental embryology, and coming from the hand of Spemann is wholly such a summary.

—C. H. K.

THE SOCIAL LIFE OF ANIMALS, by W. C. ALLEE. Pages 1–293, 5 pls., 49 text figs. 8½ x 5¾ inches. 1938. Published by W. W. NORTON & COMPANY, INC., 70 Fifth Ave., New York City. Price, $3.00.

This volume should be on the "to-be-read" list of all biologists. It gives a very lucid and well organized summary of a phenomenon of animal behavior, that of aggregate or co-operative behavior, which is such a common thing in every observer's experience that practically all biologists have overlooked, first, the facts of its existence, and secondly, the biological implications of its various types. Too much biological theory has been built on the exceptional. Allee has shown ability and even genius in recognizing the importance of the commonplace. While we have difficulty in seeing eye to eye with Allee in his placement of co-operative behavior in the general scheme of social evolution, we rejoice because he has elevated and clarified much that has been neglected and obscure in this field of study.

Allee aims at basic sociological theory from the point of view of experimental evidence. He opens the discussion with Chapter I, *Science versus Metaphysics*, which is a justification of the scientific method. This is good pedagogy as the majority of educated readers will agree with the author through at least the first chapter. The next, Chapter II, *History and Natural History*, reviews early work on aggregations and states the problem: "The conclusion seems inescapable that the more closely-knit societies arose from some sort of simple aggregation, frequently, but not necessarily solely of the sexual-familial pattern. Such an evolution could come about most readily with the existence of an underlying prevasive element of unconscious co-operation, or automatic tendency toward mutual aid among animals." Chapter III, *The Beginnings of Co-operation*, deals with the problems of optimum populations and physical conditioning of the environment. The author shows the well known evils of over-crowding and the less well known deleterious effects of under-crowding. One type of conditioned environment is where a species does better in water in which others of his species have lived than in fresh water or pure water. Chapter IV, *Aggregations of Higher Animals*, discusses conditioning in the cases of such complex animals as goldfish, Drosophilia, etc. Factors limiting populations even in the presence of ample food, fitting climate, etc., are reviewed. The extinction of species when certain low population levels are reached and the relation of gene frequency to the evolution and survival of a species aggregation are discussed. Chapter V, *Group Behavior*, covers the phenomenon of the speeding up of profitable behavior with the presence of greater numbers. An ant digs more dirt as a member of a group than when working alone. Students learn more rapidly as members of a group not too large than when studying individually. Chapter VI, *Group Organization*, deals with leadership within the group. The phenomenon of leadership is discussed from its beginnings among such animals as chickens, where the established social order is termed by students of behavior the "peck-order," to leadership in the human species where leadership among the genetically identical Dionne quintuplets is analyzed. In a social peck-order in the poultry yard one top hen has the privilege of pecking all other hens with whom she associates. The next socially eminent hen can peck all but this top hen and so on down to the lowest hen, almost a social outcast who can peck no other hen. Interesting special cases are cited. Roosters have a similar peck order. A hen in mating will usually choose the rooster of highest social standing (rooster peck-order). While reading this chapter thoughts of the social prominence of one's friends, acquaintances and enemies obtrude. Chapter VII, *Some Human Applications*, deals with human problems of overpopulation and particularly that of war. Chapter VIII, *Social Transitions*, discusses the place of sex in the mechanism of aggregations and particularly as evinced in the family life of subsocial and social animals.

The present reviewer is one who would tend to reserve the term "society" and its derivative "social," for those few animal aggregations (the "societies" of termites, ants, bees, wasps, man, etc.) which have been evolved from the family group. We have always shivered mentally when we have heard these terms used to elevate or add tone to ecological theory. Allee's long association with ecological literature may have helped fix this broader use of the terms "society" and "social."

We feel that Allee minimizes a series of basic or key factors each and all of which have to be present before the evolution of a completed society can take

place. (I am referring as above to the societies of the termites, ants, bees, wasps and man.) Some of these vital factors are: 1. Generations must overlap; 2. High intelligence (with development of memory) must be present; 3. An ample food supply; 4. High immunity to disease or in its place good sanitation; 5. Means of defense (behavior, weapons or protective nest); 6. Good tools for subduing and manipulating the environment, feeding young, etc. (mouth-parts, etc.); 7. Physical conditioning of the environment (odors, etc.); 8. A co-operative or at least tolerant behavior toward relatives; 9. Parental care for young.

No one of the above can drop out in organized society without the extraordinary development of one or more of the remaining factors to cover the lack. (I am assuming that when a species becomes parasitic it is no longer social in as far as it is parasitic.) As an example, the low intelligence of termites is offset by defence through the tightly closed nest which shuts out the problems of a difficult environment that might overtax termite behavior. It is further offset by the development of ability to use a diet largely of wood which is one of the most abundant and easily obtained foods.

Allee states (p. 49): "The conclusion seems inescapable that the more closely-knit societies arose from some sort of simple aggregation . . . with the existence of an underlying pervasive element of unconscious co-operation, etc." So they did, but they arose from animals with such co-operative tendencies plus at least eight other equally necessary qualifications for social life as listed in a preceding paragraph.

This reviewer feels that all nine of the recognized factors listed are vital to full development of social life and that aggregate or co-operative behavior is only one of this series of nine factors, however conspicuously important it may appear to a human socius who depends on co-operative behavior for his living.

I think that in time we will be able to add sexual hormones to the above list. They would be a contribution from sex and the family life and would probably be one of the perfecting agents that help develop and keep in continuous flow the necessarily high energies of the more highly developed societies.

We are an admirer of Allee for his splendid courage and for his clear vision in demonstrating the frequency and importance of co-operative behavior. Our slightly different point of view is one of differing assumptions and definitions.

—C. H. K.

ANIMALS WITHOUT BACKBONES, AN INTRODUCTION TO THE INVERTEBRATES, by RALPH BUCHSBAUM. Pages ix and 371. Hundreds of unnumbered illustrations. 6.75 x 9 inches. 1938. Published by the UNIVERSITY OF CHICAGO PRESS, Chicago, Ill. Price, $3.75.

This elaborately illustrated volume should interest any student of animal life. Chapter 24, of twenty-five pages, is devoted to insects. The work is by a member of the Department of Zoology of the University of Chicago and is planned to fit into the "Introductory General Course in Biology." As a college text in biology it is startling and a real innovation in its modernistic format. The beautiful photographs, and one seldom sees their equal, run to the edges of the page. The many pen-and-ink sketches are drawn with as much contrast as possible. The text occupies less space than the very vigorous illustrations and instead of the usual numerous heads and subheads black-face type is used in an otherwise solid text.

The result is an extremely vigorous book well worth a few hours of any biologist's time. It is designed for beginning college work but we do not see why the remarkable illustrations should not catch the eye and the attention of advanced high school students. It was published in November, 1938, and went into a second printing January, 1939. The rather diagrammatic drawings are by Miss Elizabeth Buchsbaum, the author's sister. The photographs are from many sources but many have been taken by the author.

We recommend the volume to those who would enjoy a brief review of invertebrates and to those who are interested in writing biological texts. Its various innovations in the writing of a college book are worth thoughtful consideration.—C. H. K.

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